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Vol. LXX JANUARY 1961 No. 1

ARTICLES

THE LAST GREAT HERDS OF AFRICA

THE PRIMATE'S AESTHETICS

STEPS TOWARD THE ATOM

SAILORS' SIREN

MAN AGAINST THE COLD

CELESTIAL EVENTS

MATING OF HYLA FABER

DEPARTMENTS

WASHINGTON NEWSLETTER

REVIEW

SKY REPORTER

THE SNOW BLANKET

YOUNG SCIENTIST

COVER: Magallanes Province of Chile is a desolate land of fords extending from the southern tip of the Chilean plain to Tierra del Fuego and Cape Horn. Typical of the landscape is this cliff towering over Eyre Channel, into which Eyre Glacier empties. Snow that melts by day refreezes each night into fingers of ice but, surprisingly, the lower rocks are tree covered. In this terrain live the Alakaluf, recent subjects for studies of their unusual ability to withstand frigid weather. Professor Carleton S. Coon, of the University of Pennsylvania, accompanied the expedition and his account of the journey can be found on page 56.

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WASHINGTON NEWSLETTER
By Richard W. Westwood

When the members of the House went home for biennial fence-mending "ski, and most Senators departed with minor aims, the second session of the 86th Congress left behind it a record of major accomplishment in conservation legislation. This was, in part, owing to the lack of time, but even more to an insufficient inclination to grapple with the many issues that might have had considerable significance in an election year. Thus, all pending legislation will have to start from scratch when the 87th Congress convenes this month.

The outstanding conservation enactment of the recent Congress was probably the Multiple Use Forestry Bill (now Public Law 86-517), hailed by the Department of Agriculture as "one of the most important pieces of National Forest legislation in the last fifty years." It provides by law that multiple use and sustained yield shall govern the administration of the National Forests. That is, running our Federal forest program, creation, range, timber, water, and wildlife are recognized as a part of the national interest. This is rather like blessing already established union: actually, the United States Forest Service has been administering our forests for many years. However, it does provide the Federal Forest with an official blueprint of a bluegreen-in case any of these interests tend to dominate another.

The Department of Agriculture, through an unidentified "spokesman," often points out that the new law is "a substitute for proposed wild life legislation which the Department opposed in principle." It remains to be seen whether the law's enactment will be to the benefit of any individual as an argument against the necessity of a wilderness ordinance. It is obvious that the new law will not only affect our forests but also the National Parks and the Fish and Wildlife Service Refuges.

Other enactments of the 86th Congress included a provision for cooperation between law enforcement officers and state conservation agencies in managing public hunting and fishing on U.S. Military Reservations. There has, in the past, been considerable jealousy about prerogatives and responsibilities with respect to such areas. Related in philosophy is another enacted law prescribing protection for forest cover on reservoir areas owned by the U.S. Corps of Engineers—finally enacted. To the end that such forests shall have greater value if used for recreation, timber-harvesting by sustained yield, and for other conservation purposes. Under another bill, cooperative wildlife-research units of the U.S. Fish and Wildlife Service, other Federal agencies, colleges and universities, state agencies, and nonprofit organizations are given authority in law. Such programs have been in effect for several years. Still another law provides for increased penalties for those convicted of buying or selling migratory waterfowl, thus violating the Migratory Bird Treaty Act.

Armillary Memorial

The session's closing days were enlivened by a controversy over a local memorial to Theodore Roosevelt. A historic island in the Portage, across from Georgetown, was acquired many years ago by the Theodore Roosevelt Memorial Association through public subscription. It was named for T. R. and has been administered by the National Park Service. It has been kept in a wild state, with access chiefly by boat. Supporting a varied bird life, both migratory and resident, and a population of small mammals, the island has been visited primarily by nature enthusiasts.

With the somewhat surprising announcement of the Theodore Roosevelt Memorial Association a bill was introduced in the 86th Congress, providing for the creation of a memorial that would have as its central feature a great "armillary sphere." That phrase sent some people to the dictionary, but the symbolism of this antique astronomical contraption still remained obscure. There would also have been an imposing approach, parking lots for automobiles, and other features that would have completely "memorialized" the island.

When the plans were revealed, Alice Roosevelt Longworth and Archibald B. Roosevelt, daughter and son of Theodore Roosevelt, and his grandson, Kermit, took violent exception to the proposal. They described it as entirely out of consonance with the thinking of the former President, and they found widespread support among his vast army of admirers, many of whom contended that the island should be left in a "state of nature." Opposition to the bill finally resulted in passage of a substitute proposal, providing that the final selection of any memorial should be subject to the approval of the Roosevelt family.

Pigeonholed

Lost in the final shuffle on Capitol Hill was the most recent of several versions of the Wilderness Bill. Also lost were a proposal to extend the Conservation Reserve of the Soil Bank beyond December 31, 1960, and the Chemical Pesticides Coordinating Act. This last would have required that any Federal agency planning to undertake a pest control program first consult with the U.S. Fish and Wildlife Service to determine possible impact on wildlife.

The refusal of Congress to increase by $90 million annually (from $15 million) the authorization for grants to municipalities to help construct pollution control plants is regarded by conservationists as specially damaging to progress of pollution control. The Senate also refused to accede to the 1952 London Conference that sought control of oil pollution of the seas. It was feared that, as the World Court was involved, the issue would trigger long debate, and Congress was in no mood for delay.

While Haleakala National Park was created out of a part of Hawaii National Park, other pending Federal proposals failed. The Chesapeake and Ohio Canal National Historical Park got by the Senate, but did not get to the House floor; Ice Age National Park, in Wisconsin, and Great Basin National Park, in Nevada, got nowhere at all.

Fish and Wildlife

Parking from the cockpit of a helicopter planes and spying on the lakes, ponds, marshes, and pools of the Northwest, Alaska, and Canada, U.S. Fish and Wildlife specialists have checked and rechecked the numbers of
geese and ducks in nesting areas this year. On such surveys, plus many field reports and conferences with state authorities, the Service based its recommendations for regulation of the migratory waterfowl hunting season.

Owing to dry conditions, early reports were not reassuring. With more rain in many areas, however, the late hatch was somewhat better. Stringent restrictions during the 1959-60 season cut the waterfowl kill by about forty per cent compared with the 1958-59 season, but there was still a twenty per cent drop in breeders returning north. Conditions on the Pacific Flyway were the most discouraging, and the season was cut there.

Most serious, however, was the situation confronting the redhead and canvasback, the gunners’ favorite diving ducks. Given good breeding conditions this year and next, both species are expected to make a comeback, but this year there is a closed season on both. Although duck hunters are loath to admit it, the majority of gunners are unable to identify species on the wing. So, closed season or not, canvasbacks and redheads are falling to the gun again this year. Last year the hunters were allowed one “mistake” if a “can” or a redhead showed up in the bag. Dan Janzen, Director of the Bureau of Sport Fisheries and Wildlife, says that too many gunners made a deliberate “mistake” and more of these birds were shot than should have been.

Across the board, restrictions this year again cut the number of shooters. This means the sale of fewer duck stamps, the revenue from which goes mainly for purchase of wintering, breeding, and resting areas in the form of refuges. However, it is unsafe to gamble with this wildlife resource in order to keep stamp revenue at a maximum.

During 1959 there was an increase of 382,000 in the number of those who used National Wildlife refuges. Nearly ten million such visits were recorded, although recreation is still only a by-product of the refuge system. Sixty-three per cent of the users enjoyed photography, picnicking, swimming, and observing nature, while thirty-two per cent fished. Hunting attracted five per cent.

In Oregon, Klamath Marsh serves large numbers of waterfowl on the Pacific Flyway, and is vital to the birds for nesting. Thus, the transfer—by purchase—of 11,661 acres of Klamath Indian tribal lands to the Klamath Forest National Wildlife Refuge is an important development.

National Park Service

One long-delayed national park issue that will be actively urged with the arrival of the 87th Congress is that of shore line parks, recreation areas, monuments, or whatever other name may be chosen for them. These include shore line spots along the Atlantic, Gulf, and Pacific coasts, and the Great Lakes. The list embraces Padre Island, Texas; Cape Cod, Massachusetts; Point Reyes and Channel Island, California; Oregon Dunes and Sea Lion Caves, Oregon; Indiana Dunes, Indiana; Cumberland Island, Georgia; Pictured Rocks, Grand Sable Dunes, and Sleeping Bear Dunes, Michigan. The primary objective, of course, is to protect these vanishing shore lines against the encroaching “civilization” that is destined soon to engulf them—a fate that has already overtaken the Indiana Dunes and a good deal of Cape Cod. All of the areas proposed have been intensively studied in surveys financed privately but conducted under the National Park Service.

Individual bills in favor of specific areas were introduced in the 86th Congress but failed to gain headway. A hearing on Padre Island was chiefly to let the opposition be recorded. The National Park Service favored a bill that would have jointly designated Cape Cod, Padre Island, and Oregon Dunes as park areas, apparently on the grounds that these areas deserved first consideration. Individuals had other ideas. Senator Frank E. Moss of Utah, for instance, has prepared a bill for a Great Salt Lake National Park. He is expected to hold hearings in Utah prior to the convening of the new Congress in January.

A drive to create a Cascades National Park—embracing about a million acres of the Oregon Cascades—is gaining momentum. Some of this area is now in wilderness status and much of it is also inaccessible except to the most hardy. The drive is spearheaded by the Sierra Club, and considerable opposition has been generated in Forest Service circles and among those westerners who seem to resent the idea of more National Park areas. This is going to be an interesting campaign to watch. As yet the National Park Service has had nothing to say.

This year the National Park Service observed the fortieth anniversary of its Naturalist and Nature Interpretive Service. This program includes the ranger-naturalist service, nature museums, and other implements for interpreting the natural history of the parks and monuments. Proposed to Stephen T. Mather, first director of the National Park Service, by Charles M. Gohe of Sacramento and the late Mrs. Goethe, these activities have been crowned with success. The program was suggested by similar work observed by the Goethes many years ago in Switzerland.

Within the boundaries of Joshua Tree National Monument in southern California there are 10,200 acres of non-Monument holdings. There is an imminent threat to the Monument because of projected development and commercialization of these acres. Secretary of the Interior Fred A. Seaton has sought a supplemental appropriation of $1,500,000 to buy these holdings, but this has not yet been forthcoming.

Another such threat is to Rainbow Bridge National Monument, in Utah, which could be flooded by back waters from the construction of Glen Canyon Dam—part of the Colorado River Storage Project. The law that established this project provided that Rainbow Bridge be protected by diversion dam construction, but Congress has not seen fit to provide money to implement the prescribed protection.

Recreational use of state parks receives pressure upon National Park areas, and the extent to which this is true is shown in statistics of state park attendance compiled by the National Park Service. In 1959, 255.3 million state park visitors were recorded, an increase of 17.9 million over 1958 and double the total of a decade ago. New York parks had 34.9 million visits, California and Pennsylvania parks, 22.1 million each; Michigan parks, 19.9; Ohio parks, 17.7; Oregon parks, 10.8.

1961 Meetings

Foot of March 6 to 8, 1961, the Twenty-sixth North American Wildlife and Natural Resource Conference will be held at the Statler-Hilton Hotel in Washington. This largest annual gathering of conservationists has as its 1961 theme: “Planning for Population Pressures.”

Tucson, Arizona, will be the locale of the 8th National Watershed Congress, which is sponsored by twenty-five national conservation organizations. Meetings will be at the New Ramada Inn from April 17 to 19. Field trips will visit Mt. Lemmon, in Coronado National Forest, and the famous watershed exhibit at the Arizona-Sonora Desert Museum.

What’s Ahead?

The new Congress will find conservationists wondering what lies ahead. One thing is certain. New faces on Capitol Hill will mean fresh inquiries as to where these newcomers stand on conservation—indeed, as to what they know about this important issue. Both party platforms in the election campaign took serious cognizance of natural resources and their significance to the nation and its people. But that was only a start. We must wait and see, realizing that the conservation struggle goes on and on.
A recent study of the history and philosophy of modern science

By George Gaylord Simpson

It is to that period, approximately the seventeenth through nineteenth centuries, that Gillispie's "essay in the history of scientific ideas" is devoted. Be it said at once that no clearer, sounder, or, insofar as history permits of originality, more original book on the rise of modern science is available. This is not the customary rash of previous histories or secondary popularization of technical historical monographs. It is a sophisticated, new interpretation based on the essential, original materials: the most influential publications of the historically important scientists themselves. One marvels at the erudition and labor involved in reading so much of the original literature in comprehending so many branches of science, and in interpreting the essentials for modern readers. Inclusion of some biographical information about the most important figures makes the whole study more interesting and creates a bond of personal sympathy. It also makes clear that science, however objective it may be in the appropriate definition of objectivity, is still the creation of very human individuals. Another point such biography makes plain is that science has national characteristics, here repeatedly exemplified, especially by contrasts between Britain and France.

SCIENCE in the true sense (in our sense, and therefore semantically true for us) did not arise until nature was viewed as impersonal, until rational induction from observation was given priority over logical deduction from arbitrary premises, and until no aspect of the material universe was granted the privilege of exception to this rationality. This was fully achieved for physics when, in the nineteenth century, James Clerk Maxwell could write of the relationships between theory and observation, that:

"A nature theory, in which physical facts will be physically explained, will be formed by those who, by interrogating nature herelf, can obtain the only true solution of the questions which the mathematical theory suggests."

It is an extraordinary fact that science, in this sense, arose but once in the course of history, within one human culture, and over a comparatively short span of time. The culture was that of Western Europe (excluding the Slavic countries and also, significantly, excluding Greece), a culture diverse in detail but with more fundamental unity than divergence. Prominent among the unifying factors were religions ultimately of Indo origin and philosophies ultimately of Greek origin an odyssey in view of the fact that science, the most peculiar product of that culture, was to some degree a rebellion against both. The temporal period involved was, at most, the seven or eight centuries from Copernicus to Lavoisier, at least the two centuries from Galileo to Darwin. This is the "edge of objectivity". The effect of objectivity in science is that the scientist must be able to accept a proposition, logically deduced from one of two conflicting subjective premises, with the same lack of personal emotion or affective entity, logically deduced from one of two conflicting subjective premises. Has this philosopher's atom really more than the name in common with our atom, egregiously real and disastrously "splitable"? What can truly be common to the subjective "species" as one of the five "predicables" of scholastic logic and the modern, objective species as a group of interbreeding organisms? It is unwarrantably confusing to apply, in retrospect, the one appellation science to the other? such different ways of attempting to comprehend the universe.

To the edge of objectivity is added the awareness that science is essentially a social activity. Further, science now, in the twentieth century, is essentially international. This is not to say that the Pre-Raphaelites would have been worse off than they were. The science of today is a world culture. The implications are profound and disturbing. There is an acceptance of the inevitability of obsolescence, of the absolute requirement for mental testability of any hypothesis.

The focus of the author's attention necessarily shifts. Even this rather long book could not adequately treat maps of epochs without slighting lesser contributions that are not only equally essential.
but also, in fact and in sum, the greater part of the history, Astronomy is followed only from Copernicus to Newton, for by Newton’s day the objective nature of the solar system and of celestial mechanics was fully established and what followed, no matter how important in other respects, was anticlimactic from this particular point of view. Priestley, Lavoisier, and Dalton brought chemistry essentially to the same point of objectivity, and later chemical advances receive only the most casual mention. On that criterion, physics might almost have been dropped with Newton, for he did establish the objective approach in this field. What followed was not so much an increased or broadened acceptance of objectivity in physics as an exploration of where that approach led and of changing subjective views as to the implications of its results. Nevertheless, the author does go on to follow those expanding results and shifting philosophies, and wisely so, because this reinforces and further itemizes the theme of objectivity, while also providing a perceptive history of physics through the nineteenth century. (There is a brief twentieth-century epilogue emphasizing Einstein.)

This review is written for a special audience, one with some interest in science as a whole but less in physics and chemistry than in astronomy, geology, and, above all, the biological sciences. The Edge of Objectivity has been enthusiastically reviewed elsewhere by eminent physical scientists, notably by P. W. Bridgman in Science. We may take their word for it that Gillispie’s is a major contribution, thoroughly sound, “an extraordinarily good book” as regards physics and chemistry. Astronomy has already been mentioned. Geology here receives short shrift, only twelve pages, but the author previously published a whole book, Gensis and Geology, on the crucial period in the history of that science, a book I can highly recommend as even better, within its much more limited scope, than The Edge of Objectivity.

The rest of this review, therefore, I shall devote to Gillispie’s treatment of the biological sciences, a topic of great interest to most readers of Natural History but, on the whole, apparently of least interest to the author. It is not that his treatment of biology is grossly inadequate or lacking in flashes of genius. That subject has occupied the greater parts of three chapters and his discussions of Lamarck and Darwin are quite the best available in comparable brevity and far better than the majority of recent, much longer treatments. The trouble is that in this field Gillispie is apparently less receptive, perhaps less informed, and certainly less well rounded than in the physical sciences.

His discussion of biological aspects of the central theme is, indeed, very well related to that theme. This part of the subject centers on Vesalius, who introduced objectivity into anatomy; Harvey, who did the same for physiology; and Darwin, who finally brought the whole of animate nature into the realm of objective science. If this book were only about the boundary “edge” of objectivity, and if Gillispie had stopped there, no objection could be made. However—and most fortunately for the reader—Gillispie is also concerned with the increasing grasp on reality consequent on the objective approach, and with the likewise consequent changing implications and inferences, both scientific and philosophical. As far as physics is concerned, he has taken the space and trouble to explore those broader aspects adequately for the general reader, at least, if not for the specialist. But the implications of objective biology for human life and thought are far more profound than those of physics, and here Gillispie may justly be criticized.

Some of the most important issues in biology are not even mentioned by Gillispie, although they are extremely pertinent to his theme and fall within the period treated. This is true, for instance, of cell theory—the discovery that all living things have a common organic basis—and of abiogenesis versus biogenesis—whether living organisms can be spontaneously generated or can arise only from living predecessors. Other even more profound issues are mentioned only to be brushed aside. Examples are the conflicts between vitalism and naturalism and between evolution and religious dogma.

Whatever one may think of the present status of those conflicts, they did occur and did profoundly influence the history of human thought. It is not satisfactory for a historian to imply that there were only pseudoproblems or to evaluate them offhandedly and only in terms of his own personal beliefs (or prejudices) and of the present time.

Georges Cuvier (1769-1832), founder of paleontology.
Lamarck (1744-1829), founder of systematic botany.

Gilchrist outspokenly expresses disdain for systematics, taxonomy, and classification. He carries this prejudice outside the field of biology, for he implies—without sufficient explanation—at what was mistaken in Lavoisier’s chemistry was the fault of a taxonomic proach. Within the field of biology, Gilchrist’s scorn for taxonomy has led him to overlook the facts. This is one of the few truly major themes in the history of that science; it was one of the main causes of transition from the subjectivity of creationism to the objectivity of evolution, and the complex change from biological to population classification. Gilchrist’s views on the advancing edge of objectivity than many he has detailed.

The two nineteenth-century biological species that Gilchrist does treat with a succession comparable to the scope he treats the physical sciences are evolutionism and Lamarckism. Of these, few biologists now read Lamarck (this style was never attractive), and the phrase “Lamarckianism” of modern usage would have been astonishing to Lamarck himself. Gilchrist clearly summarizes the quite different, and to us still astonishing views that Lamarck really did hold. Gilchrist further claims that the fact (almost universally over

created species was an essential preliminary to discovery of how species are created in fact. So in that sense the anti-evolutionary Linnaeus was also a founder of evolutionary thought.

No more need be said about Gillies on Darwin than that it would be impossible to imagine a better summary of Darwin’s life and accomplishments in a brief compass. The treatment of Mendel is appropriately shorter but equally perceptive, and it corrects another cliché: that Mendel’s results were not known to his contemporaries. It is, however, impossible to agree that Mendel was to Darwin what Dalton was to Lavoisier, “the one attaching numbers to the other’s quantities.” Mendel never dreamed of such a thing and had long been in his grave when British and American evolutionists took up the relationship between Mendelism and Darwinism. To review the history of Mendel’s life and work is beyond the scope of this book. It is still leading to a solution of that age-old enigma. Nitely and Weissmann, in their different ways, mistook the trail, and discussion of them will only illustrate failure to achieve objectivity.

In his review of The Edge of Objectivity, Bridgman commented that the author gave unusual attention to biology. It is unfortunately true that this is unusual. University professorships are increasingly being devoted to the philosophy and history of science, and discussions of those subjects are becoming more numerous and more learned. Still, they usually center on the physical sciences, as does The Edge of Objectivity. It is regrettably unusual for any general treatise on scientific history or philosophy to treat—-as does Gilchrist—even two aspects of biology adequately. Perhaps it is symptomatic of this to find Gilchrist saying that “Nordenskjold’s The History of Biology . . . must still serve as the best general history of the science.” For Nordenskjold’s history is not only seriously out of date but also dully pedestrian, lacking in insight, and so biased that it closes with a denial of the most important advance ever made in biological theory. We must, then, be grateful to Gillies in that he does cover some aspects of the history of biology excellently: but the coverage is still inadequate for wholly free of bias.

This is a weak form of the subject’s complex ideas are expanded now in elegant but undiluted language. It is no look for the completely unformed in science or for those who seek only a superficial orientation. It is, nevertheless, accessible to the serious amateur and for him will prove far more profitable and eventually, fascinating than the more usual, journalistic popularizations.
Great Herds of Africa
An aerial census of animals in the Serengeti National Park

By Bernhard Grzimek

The native chiefs in Tanganyika co-operated in a population census several decades ago by turning over to authorities a variety of seeds representing their subjects. Long grass seeds represented boys; little round seeds indicated girls; thick black seeds symbolized men; and brown seeds presented women. The system was simple but effective. No such enviable simplicity was possible for myself and my late son, Michael, when in 1957 we were asked to make a census of large animals in the Serengeti National Park in Tanganyika, British East Africa. Colonel Peter Molloy, then director of the National Parks of Tanganyika, requested the survey to determine accurately the extent of the animals' seasonal movements.

The Serengeti Park, which is the only national park in Tanganyika, was established for the protection of great plains animal herds and their environment. The enormity of the task that faced us may be imagined in view of the size of the park—4,600 square miles—and the erroneous belief at the time that it sheltered some million animals or more within its borders.
Motivating the census was a government plan to reduce the size of the park and to alter the boundaries in favor of Masai tribesmen. The action was to be taken in connection with recommendations set forth in an official study made in 1957. However, this study, in regard to movements of large herds of plains animals including wildebeest (or gnu), zebra, and Thomson’s and Grant’s gazelles, had necessarily been based on assumptions by others and on brief observations. The census we had been asked to make was to be of particular importance, since the herds of Serengeti are presumably the last great herds of wild animals still surviving in Africa.

The immediate concerns of our census were twofold—both to establish the number of animals in the Serengeti National Park, and to discover whether the herds were actually protected by the current park boundaries and would continue to be protected by the proposed new boundaries. In view of the great area to be covered and the terrain involved, a survey by motor vehicle was impractical. Because the plain areas in Serengeti, and much of the mountainous part as well, are devoid of trees, we decided to count the animals from an airplane.

To accomplish this project, my son and I both learned to fly a plane. In December of 1957, we began a 6,000-mile flight from Germany to equatorial Africa in a single engine Dornier 27. The Dornier, a refinement of the World War II Fieseler Storch observation plane, had been selected for the job because of the excellent visibility from its cockpit. An additional advantage of this craft was its ability to fly at very low speeds. In fact, it could remain aloft at just thirty miles an hour, which would be invaluable for making observations and would also permit the plane to operate from almost any flat area without being dependent on airfields and landing strips. The plane was painted with bold “zebra” stripes to make it easy to spot in case we were forced down.

Our original intention was to fly over the whole park area, photographing it with automatic cameras. However, we discovered that it would be necessary to fly at very low altitudes, about 2,400 feet, in order to identify reliably the different species recorded on the film. Our calculations, based on
the results of previous aerial surveys by other workers, showed that, at that altitude, we would have to make more than 50,000 vertical exposures to cover the whole area. Economically, such a procedure was out of the question. Further, the absence of landmarks in much of the area to be covered would have made it impossible to join individual oblique photographs of adjacent areas. Our solution was to divide the area of the park into districts, or zones, and to fly over each of these in parallel sweeps, counting the animals of various types included within a specific angle of vision to each side of the plane.

In establishing these zones, we tried to take into consideration natural barriers—such as river valleys and mountain ranges—so that animals would not be able to shift easily from counted into uncounted districts, thus upsetting our totals. Test flights indicated that a 350-yard-wide strip to each side of the plane could be observed accurately. The plane would have to fly at a height between 150 and 300 feet. Results of the tests showed that an observer could distinguish easily between antelope species and even classify them as adults or young at a distance of 1,500 feet. In areas where there were few animals and where scanning was easy, the strips were extended in width to 2,000 feet.

In flight the pilot navigated, and his was the responsibility of establishing the width of the strips and the sequence in which they were to be surveyed. The task was complicated by the absence of adequate maps for the area. The park had to be covered on the basis of incomplete sketches in which only large streams, rivers, parts of mountains, and a few pastures were shown. Flight courses had to be set using landmarks such as lone trees, rock outcroppings, water holes, and clusters of bushes. Sweeps were made by following compass courses almost exclusively in an east-west direction.

One thought we needed to consider about our aerial survey work was the reactions of various animals to the presence of the airplane. In practice, the reactions appeared to vary quite as much as the wildlife itself, and seemed to depend on many factors. Generally, four animals reacted little to the plane overhead, even when it flew as low as thirty to sixty feet. This held true for both Thomson's and Grant's gazelles and also for zebras, kongonis, and topis. In fact, resting Thomson's gazelles did not even bother to stand up when the plane passed sixty feet above them. Small herds of from five to fifteen zebras or antelopes would run about one hundred yards from the plane's path, often dashing across its line of flight. They exhibit the same tendency to dash across the paths of autos in the

**Plastic collar** on zebra, released to rejoin herd, solved problem of marking animals. Brightly colored material was easy to see from air and lasted months.

**Dr. Geszmer**, the Director of the Frankfurt Zoo, and his son Michael, are euthanized at Vermont's **Vermont Vultures**. to be published soon by Batten. Michael died in an airplane crash toward the end of their study. The Journal of Wildlife Management has published some of the findings that Dr. Geszmer presents in his article.
Needle-tipped bullets for “miracle” gun were difficult to prepare. Weapon was used to anesthetize wild animals, but was unreliable before modification.

Serengeti. Larger herds of fifty or more animals reacted rather differently. Gnos especially, were very nervous. They would begin to race away even when the aircraft was at a height of six hundred feet, although lone specimens did not react at all. It seemed that a few particularly skittish animals would trigger escape reactions in a herd, and others would follow suit.

Large groups of gazelles showed a completely different reaction. The herd would stay calmly in place until the plane was directly overhead, when they would scatter in all directions in a rather confused fashion, but only for the few seconds it took for the airplane to pass over them. In contrast to this behavior, zebras took note of the aircraft even when it was gliding in for a landing, with the motor switched off, at heights of as much as 150 feet. Ostriches would run only when the Dornier was very close to them. Otherwise, they showed the typical “threat” posture, standing their ground with inflated feathers and spread wings.

Giraffes were difficult to start moving and fled only infrequently. Even then, they would run only 150 feet or so to the side. If they were standing beneath trees they did not bother to move at all. Baboons would always run immediately to nearby trees.

Although hyenas with prey fled while the plane was still some way off, specimens sleeping near a water hole could not be chased away. In extreme cases they might wake up, stand, and take a long look at the plane that was disturbing them. On the other hand, wart hogs fled promptly, and on one occasion, a wart hog was spotted taking cover in a nearby burrow.

Lions reacted in various ways. In the Ngorongoro Crater, we flew over and circled about an adult male. At first he showed little inclination to react. Finally, though, he began to walk away, gradually increasing his pace. Most of the time, however, lions would try to escape detection in the grass by pressing themselves close to the ground. Although we rarely saw cheetahs, the few we did encounter simply sat where they were and showed no sign of fright. Our one leopard raced to a tree and climbed it.

Naturally, the approaching airplane occasionally caused animals to flee into strips that had already been counted. Most of the time, however, they did not penetrate the zone more than 100 to 200 yards. When conditions allowed, we flew high enough to avoid appreciable fleeing or we resorted to counting whole herds. Because of the flight reactions often exhibited by the herds, when we spot...
ed one we would gain altitude in order not to spook the animals into a previously surveyed strip. Then we would circle and count the herd without disturbing it, disregarding completely the boundaries of the strips.

Of course, the problem of how to identify herds that had already been counted was one that arose. This was an important question not only because we did not wish to upset the census by re-counting the same animals but also because we wanted to be able to trace herd movements from one part of the park to another, and further, to see if these herds were straying outside of the park’s present and proposed boundaries.

Traditional methods of marking animals include dyeing or painting their hides, and putting metal clips in their ears. For our purposes, metal clips would be useless since they could not be seen from the air. Dyeing would not work at all on animals whose hair was black, and would not work well on animals with greasy hair. In any case, it was probable that neither dye nor paint had sufficient permanence and durability to mark these animals for the length of time we thought desirable. We finally settled on marking individual animals in the herds with brightly colored, plastic collars. The brilliant color of these collars was easily distinguished from the air. Made of several layers of synthetic material, they were also quite durable, and the smooth finish meant they would not irritate the animals that wore them. At first, we were concerned about the reception a marked animal might receive from others in his herd. Fortunately, the marked animals
PUTTING collars on wild animals, however, is in one respect analogous to the classic recipe for rabbit stew that says to, first, catch the rabbit. In our case, we had to, first, catch our wild animal. This was no mean task. We had heard a great deal about a “miracle” gun manufactured in the United States, which shot a projectile containing drugs. In theory, hitting an animal with one of the needle-tipped bullets injected a narcotic and anesthetized the animal so that it might be approached safely.

We acquired one of the guns in the hopes that it would fulfill our requirements. The weapon was powered by compressed carbon dioxide, a puff of which shot the hypodermic-type projectile between sixty and one hundred feet. Behind the plunger of the projectile was a mixture of carbide and water, which produced gas to drive the plunger forward, injecting the narcotic solution into the target animal. Our first results with the device were rather disappointing.

For one, it was relatively inaccurate, and we could never be sure just how far the bullet would carry. Secondly, even when an animal was hit squarely, the performance of the bullets was erratic. Thirdly, the syringe projectiles were slow to use. The narcotic solution and the carbide and water mixture had to be loaded in the field immediately before firing. Clearly, we had to remodel the contraption to adapt it to our needs.

During a return to Frankfurt, Michael modified the weapon and tested it. The new power source was compressed air at a pressure of nearly three thousand pounds per square inch. Effective range of the weapon rose to 120 feet with reasonable accuracy. The hypodermic bullets were also modified so that the impact of hitting the target was sufficient to drive home the plunger. This meant that a supply of the darts could now be loaded in camp and taken, ready to use, into the field. It also assured that the animal would receive the full dose in the bullet, whereas, with the previous system, only a partial dose was administered as often as not.

FINDING the correct anesthetic for use on various animals proved a more difficult problem, and this took many months to resolve. The toler-
ances of different animals to a given drug varied greatly, and often, surprisingly. For example, a gnu shot with a dose per pound body weight less than that tolerated by an ordinary domestic goat was incapacitated overnight, during which time we had to watch him to see that he was unharmed by predators. However, the proper dose per pound body weight for gnus of the drug (nicotine salicylate) had no apparent effect on little Thomson's gazelles. We finally learned that they required a dose per pound five times as large as that used for the gnus. We also found that the Thomson's gazelle bucks had to be captured while lying down. While running at their speed of about thirty miles per hour, the slight effects of the drug disappeared.

Once correct dosages were ascertained for the various animals we wished to mark, the actual collaring became much simpler. The drugged animal could be approached and the plastic collar fitted to its throat. In a matter of minutes, the beast would regain its feet and, soon after that, would rejoin its companions. Only the zebrae would never let us come close enough to use the "miracle" gun.

Zebras required an entirely different, more energetic—and dangerous—approach. In the beginning, when we had tried dyeing them with picric acid, we would chase them by car, while a member of our group sat on top of the vehicle holding a long pole with a rope noose at one end. By isolating one animal from its herd, then driving alongside it, always keeping parallel to its line of flight, it would be possible to close the range until the man with the pole could slip the noose over the tiring animal's neck. The danger lay in the precarious position of the man with the noose, who had to handle the unwieldy pole while trying to maintain his seat on the roof of the bucking, swaying car. On one occasion,
Michael was handling the pole when a lurch of the car caused the tip of the pole to catch in the ground. Immediately, the rear of the pole rammed back and hit Michael's throat, inflicting a serious wound that necessitated flying him to a hospital for an emergency operation. Despite this experience, Michael insisted upon rejoining the group almost immediately.

Later we modified this method for catching our zebras. We would race in the car alongside an animal and whoever was best located would reach out and grab the animal's tail. Naturally, this is much easier said than done, and it might be noted that a zebra's tail does not afford the most secure grip desirable under the circumstances. Despite the obvious difficulties involved, we became quite proficient at this method of capturing zebra. After subduing the animal, we would fit it with a collar and let it rejoin its herd.

Sad to say, one of the greatest threats to the safety of animals in Serengeti is posed by man himself. We were made painfully aware of this during a flight undertaken for the sheer joy of flying on a beautiful day. High above the plains spread below, Michael cut the motor of the plane and we glided in silence through the clear air. As we descended, a fine line across the ground caught our attention. Gliding still lower, we saw that the line was a fence of twigs and thorny branches punctuated by occasional gaps. The fence had been raised by native poachers, who slaughtered herds for meat and to provide the souvenir and curio market with teeth, hoofs, hides, and horns of various beasts. In the gaps of the fence were wire snares that would entangle any animal trying to pass through. These fences were generally placed to intersect a migration route or trail commonly used by the herds.

The poachers were still near the fence and, as Michael touched the starter button and the engine roared to life, they dropped to the ground.
Vebuzzedtheminanefforttodrive
themawayand,duringonepass,some
ofthemdroppedtotheirkneesand
droveattheairplaneliponized
arrows. Fromthesafetyofthecockpit
theirgestureappearedfutile, butwhenthey
landedatourbase sometime later
we saw an arrow protruding from the
metalwingoftheplane.

Asidefromtheobviousobjections
tothe poachers' depredations against
"protected"animals, we were infuri-
ted both by the cruelty of the methods
used, as well as by the enormous waste
oftheanimalsso slaughtered. When
makingauto triptronwhichpoachereshad
seenthework,weoften came across
animals that had died by slow strangu-
lation in wire nooses, or had been
trapped in the snares and then dis-
patched by predatory animals. Often
the victims would decay before the
poachers arrived to take the meat.
Occasionally an animal would be
found minus its horns or paws, the
onlypartsthatthepoacherswanted.

Eventually our indignation
mounted to the point where we
took part in a raid against a group
of poachers. Two of the band were
caught, and they naturally claimed
that they had merely blundered into
the poachers' camp. The camp itself,
located in a small clearing within a
wood, might have served as the back-
drop for a scene from a Grand Guignol
performance. Wherever one looked
there were strips of raw meat hung to
dry from poles arranged to form racks.
The sunlight shining through the gory
shabs gave a bloody, eerie glow to the
camp. Tangible benefits of the raid
included the capture of three truck-
loads of bows, poisoned arrows, and
wire snares, all of which were de-
stroyed or tossed into a pit too deep
to permit retrieval of them.

Unfortunately, both American and
European tourists also complicate the
situation through their hunting trips.
It is not entirely reasonable to expect
natives to accept the idea of being
punished for hunting when they see
the hunting parties of wealthy visitors
roll through their villages in cars
loaded with trophy animals. Further-
more, most African governments have

Giraffes, left, seldom ran from the
plane. Census showed 837 in Serengeti.

Paced by car, ostrich ran more than
twenty minutes at thirty miles an hour.
diminished the value of preserves and parks by not appropriating sufficient funds to ensure that the animals in them are guarded adequately.

Before discussing the results of our aerial survey, it is desirable to pause to consider some of the sources of error inherent in making a game census under such unusual conditions. One factor that presumably could never be eliminated was the natural movement of animals from a counted strip to an uncounted one. The reverse situation also may have been encountered. We tried to minimize this problem by covering in one day areas that had no natural barriers separating them. In general, we tried to count consecutively adjoining areas.

Another possible source of error lay in the blind spot directly beneath the fuselage of our airplane. Mitigating this factor were the predominantly low altitudes at which we flew, which minimized the actual hidden area. Besides, most of the animals counted scattered to the side, out of this zone, so this was most likely not a major source of error.

More important perhaps were the long distances involved in flying to the study areas. Because of this, it was often necessary to count for more than two and one half hours at a time, a chore that led inevitably to exhaustion on the part of the counters and of the pilot, who had to rest for several hours after each trip.

The position of the sun also affected our counting. Because the strips to be surveyed were oriented principally in an east-west direction, at certain times of the day sweeps in one direction or the other might be made directly into the sun. We noticed, for example, that we sighted fewer gazelles when flying toward the sun than when flying in the opposite direction. The amount of error this produced varied depending on the species being counted. More conspicuous animals, such as giraffes and rhinoceroses, could hardly be overlooked. They could be seen at great distances and it was not likely that they might be missed. For the giraffe, rhinoceros, elephant, oryx, roan antelope, and probably for buffalo, our figures were likely to be very accurate. Elephants, rhinoceroses, and buffalo occurring in rain forests, however, were not included, because they could not be seen from the air. It is also possible that there might have been some errors in the counts of large herds of gnus, zebras, and gazelles especially considering that some herd of two thousand or more were observed during our census flights.

In summary, while it is impossible to estimate the margin of error of twenty percent that exists in the total number of animals we counted, the error should certainly not exceed that figure.
The survey results were not entirely surprising to us. Preliminary counts had shown that the movements of several species were not limited by park boundaries. During some seasons, a great many animals leave the area of the park. However, the total count of large animals proved to be 366,989, or only a third of the number popularly estimated for this reason. Regarding distribution of the animals, our findings raised a whole series of new questions.

Animals of a given species are not uniformly distributed over the entire area of the Serengeti Park but tend to form concentrations in certain places, while in other areas they may be entirely absent (see maps, pp. 12-31). Regarding giraffes, the reason is evident—they stay among trees or near water. Waterbucks were found only along riversides or in parts of the Ngorongoro Crater. Impala occurred only in heavy bush and tree plains.

Kicking up dust, a wart hog pounds across road in path of Greinke's car. When threatened, wart hogs have been known to turn and charge at elephants.
areas and were not seen on open plains. This also applied to the topi, but less strictly so. As to gazelles, the interpretation is more complicated, and the same is true for gnus. It is possible that soil types and, indirectly, the composition of the vegetation play a part. Gazelles could also be pushed from an area into a region with poor vegetation by population pressure of the closely associated gnus. Generally, the way in which one species fits into the openings left by other animal groups was conspicuous.

The upsetting fact that emerged from our survey was that every year the large herds moved far beyond the new borders proposed for the park. They remain outside this area for many months. We wanted to find out why. Michael landed in many different spots in the Serengeti to study the vegetation and take samples for analysis of the types eaten by the game and those spurned by them. The results of his research indicate that the preferred type of grazing grows, to a great extent, outside the future limits of the park during the rainy season. What grows within the future Serengeti is considered largely inedible by the animals during parts of the year. We have studied the nutritive content of the grasses and have tried soil analysis to find the reasons for the difference in distribution of various grasses. We concluded that the herds need the area that is to be taken away. Ironically, the land in the park—adequate for wild animals—would be inadequate to support the Masai’s overly large herds of cattle. The big wild herds move over the central part of the Serengeti Plains in the rainy season in large circles, always returning to the same place periodically. The situation is like that on a modern dairy farm, where cows are driven daily to new areas, returning every few days to the same spots, eating only short, protein-rich grass.

In surrounding districts we saw that large herds of cattle—protected against infectious diseases—cause soil erosion and can, in a few decades, change the land to desert. In contrast, wild herds live in a natural balance with the vegetation. Because the land around the Serengeti is more heavily settled by natives each year, I believe that if the new boundaries remain in effect, large parts of the great wild herds must surely die.
Primate's An ape provides clues to the
By Desmond Morris

A JOURNALIST once asked Picasso for his opinion of paintings produced by chimpanzees. The artist's response was characteristically original. He bit the reporter. The picture-making chimpanzees have also been known to treat their interviewers in a similar manner. Human and chimpanzee painters do, however, have other, academically rather more interesting, similarities. Just what these are when the emphasis shifts from drawing blood to drawing pictures, will, I hope, emerge from the following report.

Man has always been interested in the origins of his artistic activities and several sources of material have been probed in recent years in the hope of finding some of the answers. But these sources have not been as illuminating as was once hoped. Prehistoric picture-making, left to us in the form of cave-wall remnants, has proved far too advanced an art form to tell us much about the way it all began. Also, the present-day art of so-called primitive peoples has finally emerged as anything but primitive. It is only in the realm of child art that we have been able...
Aesthetics

origins of artistic activities

find any clues, and even in this area the influences of rents and teachers cloud the issue all too soon.
Clearly then, any new and essentially more simple form picture-making is of great experimental value. Inframan paintings and drawings satisfy this requirement, as elements of visual organization that they contain are so simple that they can be analyzed in a way that is not possible with man's more complex, image-laden pictures.

At the present time, pictures have been obtained from thirty-two apes and monkeys. Four species have been involved, the capuchin monkey— in Germany, Russia, and the United States, the orangutan in England and Germany, the gorilla— in Holland and Switzerland, and the chimpanzee in England, Holland, Germany, Russia, Switzerland, and the United States. The chimpanzee has so far proved to be the best subject; this species accounts for ten of the thirty-two animals studied to date.
The majority of the earlier primate investigations were

Unusual painting by Congo is remarkable for presence of principal design plus subsidiary fan pattern at lower right.

Calligraphy, above, is most advanced obtained from any ape at that time. Congo drew brute in third year of study.
Dr. Morris, whose report on experiments with Congo was adapted from *The New Scientist*, is Curator of Mammals at the Zoological Society of London. His book, *The Biology of Art*, will be published in London by Methuen & Co., Ltd.

brief and unsystematic but one or two involved a serious analysis of the results obtained. These were so promising that a young male chimpanzee called Congo was embarked upon a three-year experiment at the London Zoo, to provide an opportunity to study in detail the graphic potentialities of an infrahuman brain. This particular chimpanzee had proved himself to be of exceptionally high intelligence and possessed of a particularly alert and inquisitive disposition. Earlier tests with other chimpanzees had indicated that certain crude aesthetic rules could be brought into operation by this species and the goal of the study with Congo was to find out if any aesthetic principles could be formulated that would be sufficiently basic to be applied both to man-made and ape-made pictures.

Congo first started scribbling when he was approximately one and a half years old. One day he was given a pencil and placed before a piece of card. The first contact made between pencil point and card was, of course, purely accidental, but, as Congo moved his arm and a line appeared on the card, he stared at it, moving his hand more and more. He repeated the movement and made line after line until the card was covered with a network of scrawls.

Congo produced many more drawings during following weeks and it soon became clear that there was a basic pattern that was appearing over and over again. It took the form of a fan-shaped series of lines radiating from a part of the card near the animal. It was also becoming obvious that Congo was reacting to the boundaries of the card or sheet of paper given to him. A large sheet resulted in a large drawing—a small sheet in a small one. Further, his work seemed to reveal a rudimentary sense of balance.

When Congo graduated from drawing to painting, his interest became even more intense. There were occasions when attempts to end a painting session resulted in screaming and temper tantrums. This, it should be emphasized, occurred despite the fact that Congo was never rewarded by the experimenter for drawing or painting. Picture-making seemed to be completely self-rewarding.

A painting session took the following form. Congo was placed in a modified version of a child’s high chair, with a sheet of paper laid flat in front of him. Pots of paint each with its own brush, were ready for him, but out of reach. A brush selected at random was handed to him. He painted until the paint was used up and then either put the brush down or handed it back to the experimenter. The next loaded brush was given to him, and so on, each brush in turn being used in a random order until he was no longer interested in the picture. Then Congo would be given a new sheet of paper. Several paintings could be obtained thus in a session lasting about half an hour.

In early tests Congo had been given a free color choice, but the method had soon been abandoned. On such occasions, he refused to start painting until he had mixed all the colors together into a uniform muddy-brown. This we avoided by presenting him with the colors one by one. He was still able to exercise a certain amount of color preference, since he was at liberty to use each brushful of col
Variations on a theme are demonstrated in paintings by Kongo, more than ninety of whose pictures contained basic fan patterns. Open, loosely knit fan motif is evident in top picture, while bottom effort has closed, crowded look.
Convoluted dark strokes that seem to overpower lighter shades in painting above, lending it “violent” appearance, contrast sharply with paler coloring and relatively clean, simple brush strokes in the chimpanzee’s work shown below.
As in the case of the earlier drawings, the paintings were always scaled in proportion to the size of the paper on which they were painted. Also, the basic fannaped pattern was often still utilized. Congo was becoming much bolder now and frequently worked without hesitation, quickly covering the paper with determined strokes. Perhaps his most remarkable painting is one shown on page 23 (top). Rays of a basic fan pattern are just discernible, but, in addition, there is a quite distinct and well-formed subsidiary fan motif in the lower right-hand corner of the picture. Previously, it had always been argued that the fan pattern was the result of a simple motoric rhythm in which the animal repeatedly pulled the brush toward himself from a series of different starting points, thus inevitably giving rise to a pattern that gave the impression of being visually controlled. As long as the fan pattern as always focused on Congo, it was impossible to decide whether the design was the secondary result of a kind of gymnastic repetition or whether it was an indication that the chimpanzee was capable of a visually disciplined pattern formation. The fact that the subsidiary fan motif here has its own quite distinct focal point strongly supports the view that the chimpanzee was doing something other than a simple muscular exercise.

In order to test the extent to which the form of Congo’s paintings was under visual control, a special series of experimental sheets was prepared. The fundamental question was this: Was the position of a line that is about to be drawn in any way determined by what is already present on the paper? If the initial markings on the paper are not made by the chimpanzee, but rather by the experimenter, then any influence that the markings may have on subsequent markings by the animal must be visual.

More than two hundred experimental drawings have been obtained from Congo and they are still being analyzed, although they reveal already that visual control in fact operates to a remarkable degree. Painting was abandoned for this purpose, in order to simplify the linear entities for accurate measurements. A black crayon was first used by Congo, who was allowed to draw with it until lost interest, and then another sheet was put before him. Colored crayons were not used to boost his interest in a passage, as this would have rendered analysis of the line situation too complex. The simple scribbles Congo made during these tests have already revealed several basic rules of chimpanzee “composition.” Some of these rules are illustrated by the drawings on pages 24, 27, and 29.

A simple fan pattern as drawn by Congo on a blank sheet of paper is illustrated on page 24 (top). When a two-inch square was placed in the center of the paper before he was handed to him, a design similar to the one shown above (top) resulted. In this test and in all others where Congo was offered a centrally placed figure, he responded by confining almost all his lines to the region of the figure. This tendency to mark over well-defined figures came into conflict with another tendency, however, if the square was placed off-center. There was still an urge to mark it, but the more the square was positioned to one side or other of the paper, the more Congo tended to counterbalance it with his markings, rather than merely to mark it (third example above). In practically every one of the many off-centered test papers placed before him, Congo made bold markings on the side of the paper opposite the figure.

These early results reveal that in the chimpanzee there is what we might call the germ of visual composition, and
Central vertical line, top, is normally ignored in the ape's drawings. If line is moved to right or left, however, Congo marks only larger, opposite part of paper. Drawings of the chimpanzee show nascent sense of visual composition.

a whole host of new questions immediately springs to mind. They are being investigated, but even now it is nevertheless quite clear that the basic visual rules that control composition and design in painting by human beings are shown in a rudimentary form in the work done by Congo.

So far, the position of Congo's lines on the paper has been discussed, rather than the lines themselves. It is interesting that although Congo's sense of visual balance has been present in the same form almost from the start, his "calligraphy" has been changing gradually from month to month. In all the early pictures the lines were short, simple, and disconnected. Even the longer lines, which soon appeared as the rays of the fan patterns, were, when taken individually, comparatively simple. But, as he grew older, Congo began to experiment with longer, more meandering lines. Soon he was experimenting with loops and spirals and, after a while, complex multiple-horizontal scribbles appeared. At his present age of roughly three and a half years he has just arrived at the circle as a new motif. Naturally, with these more complex lines, the earlier fan pattern is rapidly vanishing from his picture-making, although he will sometimes combine the fan configuration with horizontal scribbling to produce complex patterning. These calligraphic changes are particularly interesting when compared with those that take place in the very early scribbles of human infants. In almost all respects they ap-
ear to be identical. Human infants of similar ages pass through the same stages from simple, short, disconnected lines to longer, simple lines, to meandering lines, to loopings and spiralings, to multiple scribbling and eventually simple "diagrams" such as circles, crosses, and squares. This process of simplification from the confusion of multiple scribblings to the formation of distinct and simple diagrams is of vital importance in the development of man picture-making, for it is from the combining of elementary diagrams that the earliest crude pictorial images are formed that, by a rather lengthy process of differentiation, eventually lead to accurately representational imagery. It is remarkable that such decidedly similar early stages of calligraphic development are to be found in a different species, and one cannot help wondering at this point in the experimental process just how far any chimpanzee will ever be able to grope along this path of pictorial differentiation. Only after many more chimpanzees have been induced to abandon the branch for the paintbrush will we have finally found the answer to this really fascinating question.

Early effort is eyed by Congo, who began to dabble in the arts at London Zoo at age of one and one-half years. His three years' yield of hundreds of drawings and paintings may give clues to origins of image-making by human beings.
The Egyptian and Sumerian beginnings of cosmological theory

By Simone Daro Gossner

The fundamental purpose of astronomy is to understand the structure of the world around us. Our whole concept of the universe and of the laws that govern it—in other words, our cosmology—must be derived from the observed behavior of the sun, the moon, a handful of stars, and myriad luminous specks in the night sky.

Even in the early stages of civilization, men could not fail to note the daily rising and setting of the sun and moon, and the phases of the moon. The succession of seasons is associated in their minds with the periodic return of certain stars in the evening sky. Awed by the inexorable rise of celestial bodies, they invested them with supernatural powers. It is not surprising, therefore, that the cosmologies of ancient peoples were invariably linked with their religions and mythologies.

In later centuries, after astronomy had evolved into a science, cosmological theories became concerned with the rational explanation of observed phenomena. With its ocular touches of prophetic insight, its frequent backhanging, and its alternating submission to—and rebellion against—the pressures of prevailing philosophies, the progress of cosmology in the Western world from earliest times to the present day is a remarkable illustration of the steady outgrowth of scientific thought. Because of the particular cast of this subject, which cannot be dismissed in a few paragraphs, we propose to depart somewhat from our storny Sky Reporter format. From now until Deuteronomy, we shall examine successively ten of the principal periods in the history of cosmological theories.

The most ancient civilizations seem to have developed almost simultaneously in Mesopotamia—between the Euphrates and the Tigris—in Egypt along the Nile, and at Chichen Itza on the Indus Delta. We know very little about the Indus Valley culture, because its script is as yet undeciphered. On the other hand, our century-old knowledge of Egyptian hieroglyphics and the painstaking translation, in recent years, of Sumerian and Babylonian cuneiform tablets have revealed very plainly that the denizens of these ancient cities had already acquired some astronomical knowledge.

The earliest known Egyptian calendar, for example, is based on a solar year, but the fact that its months have thirty days indicates that it replaced a more ancient one based on the phases of the moon. Little doubt remains that the periods of these two astronomical bodies were known to some degree of accuracy by the middle of the fifth millennium B.C. However, the earliest written documents of anthropologists have so far date only from about 3000 B.C. Thus, for practical purposes, the dawn of astronomy belongs to the predynastic era in the history of Ancient Egypt. One can only speculate on the thought processes that fashioned his first ideas on the universe.

The dominant factors in the life of ancient Egypt were the annual rising of the Nile, which renewed the fertility of the land, and the daily course of the sun, which dispelled the dreaded night. A man’s world was the flat piece of land on which he dwelt, limited by a circular horizon and surmounted by a domed sky; he traveled to other cities by boat along the river: above all, he lived a well-ordered life. Much of this is mirrored in his interpretation of the physical universe and of natural phenomena.

The sun was seen as sailing through the day on a celestial Nile. Since it reappeared in the east every morning, there had to be another river or sea in the underworld by which it completed its course. The earth was a disk held aloft on these waters by the earth-god Geb. Nut, goddess of heaven, stood arched over the earth (see picture at left), her body studded with stars. The obvious discomfort of her pose was eased by the proffered support of the air-god Shu. Oddly enough, this myth does not account for the diurnal and annual motions of the stars. Yet these motions must have been known from earliest times, because the abode of the dead was thought at first to lie in that part of the sky, near the celestial pole, where constellations never dip below the horizon (at a later period, the underground sea played a similar role).

Another, perhaps older, myth describes the sky as a cow with stars attached to her body, and some texts speak of the four pillars of heaven, which were believed to support the celestial sphere. The story of Nut, however, seems to have endured in Egyptian mythology for several thousand years, at least until the beginning of the Hellenistic period in the fourth century B.C.

We know very little about the Sumerians, who preceded the Babylonians in Mesopotamia. The decipherment of their clay tablets is a slow and laborious task, but the available texts unfold a rich and imaginative mythology, much of which reappears in slightly disguised form in Babylonian and Greek fables.

There is no text devoted exclusively to Sumerian cosmology, but numerous references scattered among their legends make it possible to reconstruct these most ancient beliefs. In this rugged country, submitted periodically to the heavy floods in the Euphrates Valley and to the pummeling of severe windstorms, water and atmosphere appear as the most important elements of the universe.

The earth was viewed as a flat disk encased above and below in a solid sphere—presumably made of tin—and completely surrounded by water. The air-god Enlil separated the sky from the earth by the sea mother Tiamat. The sun, moon, and planets were deemed luminous emanations of the atmosphere. As in Egypt, several thousand years must pass before a semblance of rationalization becomes apparent. Even the later and more sophisticated Babylonians, contrary to popular belief, seem to have based their astronomical calculations on empirical rules rather than any accumulation of theoretical considerations.
THE SKY IN JANUARY

From the Almanac:

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Moon</td>
<td>January 1</td>
<td>6:06 P.M., EST</td>
</tr>
<tr>
<td>Last Quarter</td>
<td>January 9</td>
<td>10:03 P.M., EST</td>
</tr>
<tr>
<td>New Moon</td>
<td>January 16</td>
<td>4:30 P.M., EST</td>
</tr>
<tr>
<td>First Quarter</td>
<td>January 23</td>
<td>11:14 A.M., EST</td>
</tr>
<tr>
<td>Full Moon</td>
<td>January 31</td>
<td>1:47 P.M., EST</td>
</tr>
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On January 2, the earth will be at its shortest distance from the sun (perihelion) for the current year.

For the visual observer:

Mercury will be in superior conjunction with the sun on January 5, entering the evening sky on that date. Thus it will be too close to the sun for observation during most of the month. At month’s end, it will set about an hour and fifteen minutes after sunset but, even then, it will be very low in the sky, to the west–southwest.

Venus, in the evening sky, will brighten from $-3.8$ magnitude on January 1 to $-4.1$ the night of January 31. Its greatest eastern elongation is on January 28. Very brilliant in the west, it will set three and a half hours after sunset on January 1, four hours after on January 31.

Mars, in Gemini, will be visible most of the night this month. Its distance from the earth will increase from 57 million miles on January 1 to 69 million on January 31, with a corresponding decrease in brightness from $-1.3$ magnitude to $-0.5$ magnitude. It will pass nearly overhead at about midnight, local time, on January 1, at 10:30 P.M. on January 15, and at 9:30 P.M. on January 31. It will set shortly before sunrise in early January, one hour before at midmonth, and about 5:00 A.M. on January 31.

Jupiter, in Sagittarius ($-1.4$ magnitude) will be in conjunction with the sun on January 5 and will be lost in its glare during most of the month. By January 31, it will rise one hour before the sun but may be still difficult to see in the morning twilight.

Saturn ($+0.8$ magnitude) will be in conjunction with the sun on January 11. Only a few degrees will separate it from Jupiter, and it will be equally unfavorable for observation by reason of its proximity to the sun.

The Quadrantid meteor shower will occur on January 3. Unfortunately, the moon will be two days past full on that date and will be bright enough to obliterate the fainter meteors. This shower tends to reach its peak abruptly, and the number of trails visible to a single observer may vary appreciably from their predicted rate of 40 per hour.

An unusual star group:

The brightest star in the constellation of Gemini (see map) is most remarkable. It consists, in fact, of six stars in such close association that their combined brightness makes them appear as the single object we call Castor. Two of the six components form a binary system revolving around each other in a period of nine days. Two others form another binary system with a three-day period. The two binaries themselves revolve around each other in about 350 years. Finally, the remaining two stars in Castor form a third binary (with a period less than a day), which slowly revolves around the quadruple system described above, in a period estimated at a few thousand years.

This year, Mrs. Gossner presents a series on the growth of cosmological concepts. This is the first of the series.
MAGNITUDE SCALE
-0.1 and brighter
0.0 to +0.9
+1.0 to +1.9
+2.0 to +2.9
+3.0 to +3.9
+4.0 and fainter

TIMETABLE
January 1 10:30 A.M.
January 15 9:30 A.M.
January 31 6:30 A.M.
(Local Standard Time)
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This is the 109th of Nature Magazine's special educational inserts
Weather changes as the form of water in the air alters the amount of water vapor present. Extremely cold air is much drier than that ranging from 24° to 30° Fahrenheit, between which two temperatures the heaviest snowfalls take place.

THE SNOW BLANKET

Management methods can make snowfall an asset or a liability

By E. Laurence Palmer

The inhabitants of the continental United States—with the exception of those living along its extreme southern border—are accustomed to annual, or at least occasional, snow blankets. In some places, the snow blanket may be permanent. In other places it may last only a few hours or days. In thickness, the yearly accumulation may vary from less than one inch to more than eight hundred inches.

The snow blanket may remain in a fixed position, may move almost imperceptibly, or, as an avalanche, may move unpredictably and at great speed. It may possess characteristics that can, within certain limits, be profitably utilized by humans. It also has its disadvantages, which to some extent can be nullified.

A snow blanket is both an asset and a liability, a joy and a threat, and a thing of beauty. Unmanaged, it may also represent a prodigious waste of a precious resource. In spite of the fact that its existence is almost universally known, its role in the scheme of human life is generally little understood. Although the snow blanket may take a life or save one, its management has received only slight attention.

Playwrights, artists, musicians, poets, engineers, and outdoor people all make their own special interpretations of the role that snow blankets play in their own lives; but for the most part its existence is ignored by the general public, whenever possible. Snow blankets offer a challenge to industry, agriculture, commerce, and practically every other phase of human activity; but they rarely, if ever, are subjects for study in our schools. They deserve to be better understood.

The history of a plant or animal follows a definite sequence, from birth to death. It is a sequence that cannot be reversed, even temporarily. But the history of a natural phenomenon, such as a snow blanket, can be a sequence, or series of sequences, whose order may, and often is, repeatedly reversed.

Basic to the creation of a snow blanket is the water vapor of the air. The abundance of the vapor varies with temperature, wind direction, and other factors. Warm air is capable of holding more water vapor than cold air; and, as the warm air cools, it loses its vapor in the form of fog, rain, or snow.

The physical form of the precipitation is largely determined by temperature. Above the freezing point,

Dr. E. Laurence Palmer, for many years director of Nature Magazine’s educational program, continues his special inserts in the pages of the combined magazines.
water in the air returns as rain, which is not ordinarily part of a snow blanket. Below the freezing point, precipitation may occur as snow. Large, lacy flakes are formed at relatively low altitudes and high temperatures. Under conditions of high altitudes and low temperatures, water vapor may be precipitated to earth in the form of fine discs and plates of ice.

The discs and plates are ordinarily three- or six-sided planes. If the bits of solid ice fall through drier air, they may, by sublimation, be re-absorbed without assuming a liquid form. Even after the flakes reach the ground and accumulate in snowbanks, they may return to the air as water vapor through sublimation, without adding to the water of the earth’s surface.

As a blanket, snow may permit the passage of light and allow for changes in temperature, as well as some movement within itself; but, in general, snow blankets act to retard changes and to temper extremes. Such changes can be controlled in greater or lesser degree by human management of snow.

Food production is, of course, an important element in the sum total of the nation’s economy. For a number of years past, in the United States, more and more food has been produced by fewer farmers, on less acreage. This state of affairs is largely attributable to the utilization of machines, in combination with a more intelligent management of the land. Such management has taken the snow blanket into account and has related it to sustained water supply, reduced soil erosion, and the mitigation of weather damage.

We cannot produce snow at command. We can, however, by the wise use of barriers, anchor the snow blanket, to the end that the frost line in the ground may be kept nearer the surface, so that water may penetrate the soil to build up underground water reserves on which we can draw in the future.

Shelter belts, terraces, strip-cropping, and good wildlife management practices prevent many crises associated with soil freezing, too-rapid melting of the snow blanket, and wind and animal damage. Where snowfall is light, the ground may freeze to a depth of more than six feet during early winter. A snow blanket of a foot or more depth during the bitter weather of January and February may prevent the soil beneath it from freezing to a depth of more than a few inches.

Snow-covered brush pile offers haven to small animals that are hard-pressed to find shelter in leafless winter woods.

Crops like winter wheat, protected under the snow blanket, survive where they would otherwise be destroyed. Facts like these accentuate the real worth of the snow blanket to the agriculturist.

To the city dweller, a snow blanket is usually nothing more than a nuisance, or a seasonal novelty. In reality, however, it is a phenomenon of major importance to city and countryman alike, and is likely to have a far-reaching effect on both.

If an unduly heavy snow blanket has an adverse effect on agriculture, this will be reflected in prices and farm profits. With the coming of snow, human transportation problems increase, and the problem of snow removal may seriously deplete the financial reserves of a town or a state. Snow and slush may affect human health, and consequently the earning power of those engaged in making, marketing, and using the items that go into the national product. Winter conditions, on the other hand, create a demand for special clothing, which in turn is reflected in additional consumption of raw materials and an increased demand for labor in many different industries—from shoemakers to hat manufacturers.

The snow blanket also produces seasonal situations that affect the yearly earnings of people engaged in outdoor labor. New home construction, for example, may be suspended during the time that a heavy snow blanket covers the ground. The weight of the snow blanket on buildings may even affect the nature of local architecture.

Snow conditions have an effect on home problems such as heating budgets and the need for special snow-removal equipment. Many winter casualties are directly traceable to unacclimated physical exertion on the part...
Sudden melting of a deep snow blanket during unseasonably warm weather or after heavy spring rains can produce floods of persons faced with the chore of keeping driveways and walks passable. Snow, then, has both a direct and an indirect role to play in the economics, the health, and the living conditions of the nation's inhabitants, and its industrial and commercial life.

Stories carried by press, radio, and neighborhood chatter tell of the troubles that may be caused by a snow blanket. Slippery surfaces bring an increase in the accident rate. Some snow-caused accidents are fatal; others are crippling; still others are painful, inconvenient, or embarrassing. An increase in vehicular accidents, both expensive and disturbing, arrives with the snow blanket. The snow may perhaps defeat the purpose of a special department store sale, with its expensive preliminary preparation. Theatrical, political, and sporting events may fail because of an abnormal snowfall. School activities may be suspended during and after heavy snow storms, and lost school work must be made up, if possible. It is even conceivable that political meetings could reach unforeseen conclusions, and new faces appear on the face of government. The economic effects are incalculable in soil erosion and loss of water.

Light aids in the management of the snow blanket, and roads absorbing or reflecting light help regulate snow clearance.

Depth of the snow blanket has great effect on an animal's ability to move, find food, keep warm, and avoid predators.
Windbreaks, such as trees planted between fields, may cut damage caused to farm land by wind damage and heat loss. A planting also helps to control the amount and the speed of spring runoffs, and to prevent any serious soil erosion.

A political scene, because of the limiting effect of a heavy snowfall on some of their participants.

Snow blankets are capable of wrecking orchards and shade trees, and of disrupting communication systems. They may sometimes lead to human death by starvation or by freezing. The sudden disappearance of a deep snow blanket during unseasonably warm weather or because of heavy spring rains may produce floods destructive to cattle, crops, and humans. Even the absence of a normal snow blanket may be a menace. Such a condition may well contribute to drought during the seasons that follow. It is fair to say, then, that the snow blanket, without management, may be considered a potential menace to many aspects of human welfare.

A snowbank is an agency of moderation. It functions as a bridge between extremes of heat and cold, drought and flood, starvation or survival. Fluctuations between such extremes may occur over short periods of time, in short units of space, and in small units of abundance. Each special situation may be a critical one, not only for
I

Tiny 40 Muskrats, Avalanches above, result can live from in snow snow fatally and fallmg definite may be benefits in steep slushy by water. birds. — shelter might opportunities to interpreted. the the to the time tem, stand like heavier rabbits, become of legs advantage of of the crust, — heavier animals like rabbits, just as a dog may take advantage of a larger and heavier deer in a life-or-death pursuit through deep snow. The snow crust also may act as a death trap for birds like grouse, which often bury themselves in soft snowbanks; or to pheasants, whose long tails may freeze into the snow while the bird is at rest. The snow blanket may deny life to animals of all kinds by forbidding them access to ordinary food sources. Particularly interesting, from the human viewpoint are the trails left by wild animals in the snow. Such trails are rather easily identified and interpreted. The thirty-seventh number in this series, under title of “He That Runs May Be Read,” described and illustrated the tracks and trails of more than a hundred wildlife representatives.

In the earlier days of the nation, human survival often depended on the ability of the inhabitants to understand the snow blanket and, if possible, to take advantage of it. Even today, crises in our modern transportation system, or perhaps the sudden outbreak of war, might at any time force us to cope with a snow blanket on a most serious — perhaps even a life or death — basis.

On the lighter side of the picture are the recreational opportunities offered by the snow carpet to children and adults alike. Children, of course, enjoy making snowballs, snow men, and snow “forts.” In a more serious vein, it might be suggested that, in connection with the civilian shelter programs that are now being carried on in various areas, each community could, during the proper season, erect a few good snow shelters. Such shelters might well serve as temporary havens in times of sudden emergency.

Igloos, similar in many respects to those of the Eskimos, may be constructed of blocks of snow that have been hard-packed by trampling. The snow is cut into blocks about three feet long, one and a half feet wide, and a half-foot thick. The igloo, or snow house, is best built on a base of
hard-packed snow at least three feet thick. (You will find the essential steps in the construction of an igloo illustrated on page 46.)

Thirteen blocks of the indicated size are placed on edge in a circle on the base. Beginning at the bottom of one of the blocks, and ending at the top of the preceding one, a spiral is marked on the circle of blocks, and the blocks are cut accordingly. As indicated in the sketch on page 46, the blocks are so placed as to form a dome, and an entrance cut to form a heat-trap below floor level. In such a snow house, if it has been carefully made, food may be stored, and two people may sleep in relative comfort and warmth.

Interest in winter sports, which are dependent largely on the depth and quality of the snow blanket, has increased phenomenally in the past decade or so. Winter games of national and international flavor are becoming increasingly commonplace. The weekend exodus of hordes of city dwellers, equipped with skis and other sporting paraphernalia, is a familiar sight on our highways today, and rivals the summer migration to the country's many lakes and beaches, or camping sites.

Such winter sports are, of course, based on the slippery nature of accumulated snow. To most youngsters, the sled is a basic instrument. Their elders may pursue the art of bobsledding, with experienced and trained participants contributing to both records and safety. Tobogganing is, of course, a much slower and safer form of winter sport—unless the participants happen to strike a patch of ice at the bottom of the toboggan run. Snowshoeing is slower yet, but has its rewards for vigorous folk. It is an art still practiced by many trappers, miners, foresters and hunters, and is the occasional resort of rescue workers in times of blizzard.

A natural phenomenon as universal as the snow blanket must find its place in the arts, as well as in science and economics. Homely words about snow have a place in our everyday conversation, and we are delighted by the word-pictures drawn for us on the subject of snow by the writers of prose and poetry. In the celebrated poem, The Night Before Christmas, we hear of the moon on the crest of the new-fallen snow, and how it gave “the luster of midday to objects below.” A picture of some of the grimmer aspects of snow can be found in the Jack London story, “To Build a Fire.”

Snow always seems whiter than a Monday's wash, even after the latter has been subjected to the most efficient and widely advertised detergent, and somehow the word “chaste” creeps into many descriptions of snowy scenes. One poet speaks of the “double trial of perfect snowflakes,” with a degree of scientific accuracy. A more practical soul tells us that “The snow had begun in the gloaming,” and continued on through the night to successfully alter the appearance of the land.

Writers of proverbs tell us that a “Snow year is a rich year,” and that “a year of snow is a year of food.” They also say that “snow which lies fattens the land,” and that “crops under water presage famine, and under snow, bread.” Farmers once referred to snow as “poor man's fertilizer.” A particularly vivid feeling for snow may be found in the introductory paragraphs of the story “Krag the Kootenay Ram” in Ernest Thomas Seton's book, Lives of the Hunted.
<table>
<thead>
<tr>
<th>WATER VAPOR IN AIR</th>
<th>DESCRIPTION</th>
<th>FACTORS INVOLVED</th>
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<td></td>
<td>Air at various levels above the earth's surface varies greatly in temperature, weight, water vapor content, movement, barometric pressure, and other factors. Change in form of water in air produces rapid or slow changes in amount of water vapor in air, with corresponding changes in weather.</td>
<td>Air at 0° F., holds about ½ the moisture it holds at freezing, while air at -30° F. is about five times as dry as air at zero. Heavy snowfalls occur when temperature ranges from 24° to 30° F. Changing of water vapor into snow may affect the air temperature of an area for some time.</td>
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| CONDENSATION | Snow crystals are usually 3- or 6-angled frozen planes of water sometimes paired, parallel, and connected. They may be rather even-matched disks, or elaborately but symmetrically fragmented along their margins. May be compacted, through violence, into tiny spherelike pellets. | Crystals formed at high altitudes and low temperatures are usually of the thin, regular, disk type; while those formed at low altitudes and relatively high temperatures are of the loose, feathery type. Either, or both, may be changed into pellet type by violent wind actions; may be intermixed. |

| SEDIMENTATION AND STRATIFICATION | Snow falls to the ground under varying conditions of temperature, violence, and humidity. In the United States, there are places having annual accumulations up to 800 inches. Others receive less than 1 inch. Fallen snow is subject to either slow or sudden changes over periods of a day or longer. | New-fallen snow may be mixed with greater or lesser amounts of air, and is variously affected by changes of air and temperature. Snow forms a useful thermal blanket that limits sudden changes; if a crust is formed, temperature differences in a vertical inch may easily exceed forty degrees. |

| EVAPORATION AND SUBLIMATION | Much of the accumulation of snow in any area may never contribute to raising the local water table, to filling depleted reservoirs, or to restoring other water reserves that may be needed in time of drought. Much may be lost by immediate evaporation, or by sublimation of snow into the air. | Air at an excessively low temperature is relatively dry. Sublimation of snow—the changing of solid ice into water vapor without melting—builds up water vapor in the atmosphere, reduces the hazard of frost, and even of future melting, and tempers the potentially dangerous changes of the spring season. |

| MELTING | Melting of the snow cover brings an element of danger as well as many problems of water management. Warm rains may melt deep snows rapidly and swell streams. Although rapid melting may cause floods and destruction, such changes are all a part of nature's transition to the growing season. | Direct sunlight, the arrival of warm winds, and the lengthening of the day may accelerate melting—advantageously or otherwise—and means of controlling rapid melting should be understood. Forests or tall weed cover may provide enough shade to produce significant lag in melting. |

| METAMORPHOSIS | As with most things in nature, change is the order of the day with snow and the snow blanket. Newly fallen snow is almost immediately subject to pressures from adjacent snow, to changes in temperature, and often to abrasion by movements of adjacent objects. Changes or metamorphoses result. | Changing of water from a solid to a liquid, or a liquid to a gas—or the reversing of such processes—involves considerable heat transfer in one direction, and may have considerable effect on the base on warm ground and its surface exposed to cold air, provides a setting for great variations. |

| TEMPERATURE MANAGEMENT | Management of any area presupposes an understanding of temperature variation, based on surveys, showing differences due to vertical or horizontal position, of compass direction, and to the nature of adjacent areas. It should also take into account the available means of insulation. | While ideal snow management is beyond man's control, planning can frequently reduce the hazards involved, within limits. Windbreaks may temper wind damage and heat loss, while color may contribute to heat absorption from the sun. Presence of a snow blanket definitely affects thermal strata. |

| WEIGHT AND IMPACT PROBLEMS | Weight of the snow cover may destroy some trees and other plants by weight alone. Ice-glazing may be even more destructive, not only to plants but also to the works of man. Because of the impact of dense masses of falling snow, certain types of pressure, and other factors may be destroyed. | The weight of animals moving over snow affects their ability to escape capture, particularly as large animals cannot travel as lightly over snows and crusts as smaller animals. Snows compacted by the feet of animals into runways may possibly provide a record of the animal's search for food. |

<p>| LIGHT | Light and its associated heat does much to regulate the life and extent of a snow blanket, large or small. Normally, snow vanishes more quickly from areas exposed longer to the sun. This creates sharp contrasts in events that take place above or below ground in such localities. | Angle of the sun, and the color, size and nature of extraneous materials on the snow affect the melting rate of a snowbank, as well as the volume of consequent runoff. Light absorbed by, or reflected off, a blanket must be considered, along with light penetrability of snow blanket. |</p>
<table>
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<tr>
<th>WILDLIFE ROLE</th>
<th>MANAGEMENT</th>
<th>ECONOMICS</th>
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<td>Dryness of bitter cold air may affect survival of wildlife, its endurance, and consequently its behavior. When invisible water vapor in the air changes to visible fog, or vice versa, the ability of animals to move about, find food, and avoid enemies may be affected in various ways.</td>
<td>Fog blankets are frequently used to delay killing of flocks in orchard areas, and snow, often associated with fog, may be used as a management tool. It may also be a health and safety hazard, particularly in cities, where smoke control is poor, and where water vapor may be highly concentrated.</td>
<td>Real estate values, crop values, recreational values, and health values may all be profoundly affected by the water vapor content of associated areas. Expense of snow removal connected with water content of the air may mark the difference between economical or expensive existence.</td>
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<td>Newly formed snow in air may limit visibility considerably. Quick freezing produces small crystals that do not rupture cells of stored plant or animal matter and, by prolonging the usefulness of stored materials, reduces the demand for wastefully large harvests of fish, birds, and game animals.</td>
<td>Snow and ice crystal management is based largely upon prevention of accumulation. Thus, variations in temperature, in amount of available air, and in pressures induced by weight may be stabilized and used to advantage by men and other living things. Man's influence is most active.</td>
<td>Snow in the air contributes greatly to weather accidents by limiting vision. Fragmentation caused by formation of ice crystals in growing crops, in stored supplies, in farmed soils, must be controlled to produce a sound economy, whether in an organism, a community, or a large territory.</td>
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<td>A snowbank is rarely homogeneous from top to bottom, and its nature largely determines the ability of living things to survive and to move about under the snow cover. Variations in weather may be recorded in snowbank strata, in glaciers, and in other such frozen accumulations.</td>
<td>Snowbank management involves preservation or elimination of snow to meet the needs of organisms that normally move about on their surfaces; those that burrow between their upper and lower surfaces; and those that explore the base of a bank where food may be abundant and enemies rare.</td>
<td>Stratification of a snowbank is a continuation of the physical variations observable above and below the snow accumulation. Management of the snow stratum may be of economic importance to farmers who raise winter wheat; or to those whose orchards may be destroyed by mouse damage.</td>
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<td>The orderly reduction of accumulations of snow by sublimation greatly reduces the dangers and problems of wildlife living where snowfall is substantial. Snow is the process, for the most part, that it is not recognized by many; it is, however, an important factor in the water cycle.</td>
<td>The loss of water through sublimation from exposed plant tissues may contribute considerably to winterkill, affecting the physiology of plants much as would freezing to ice. This happens at a time when water losses cannot easily be restored, because water is held in the ground by freezing.</td>
<td>Sublimation of water from exposed plant tissues can, of course, be prevented by maintaining a snow cover until such time as losses may be replenished. This is a part of the problem consists of nothing more than the preservation of helpful mulches of snow and other materials over plants.</td>
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<td>Melting snow and ice may open water surfaces to air, permitting a buildup of exhausted oxygen resources in water surrounding edible fish and associated animals. Snowbanks may delay melting of frozen water at soil surface until season is settled, avoiding losses due to rapid changes.</td>
<td>Melting speeds may be influenced by judicious planting of shade-producing crops, by use of mulches, or by removal of vegetation. Removal of snow accumulation in highlands may provide useful information in prediction of time and volume of possible flood waters produced by melting.</td>
<td>Floods may destroy great volumes of valuable top soil, as well as young growing crops. If delayed, they may influence a crop or future food for birds, or even the whole economy of a tract of agricultural land. Deposition of undue amounts of silt following floods may ruin a crop year.</td>
</tr>
<tr>
<td>The hardness of parts of a snow cover provides both conveniences and difficulties for wildlife, which, because of food and survival needs, must move through the snow. Such movements must be well timed to avoid the traps of man and many other hazards, both natural and artificial.</td>
<td>Activities of man and other hunters are often governed by recognition of the fact that a snow crust makes escape or pursuit difficult or easy, depending largely on the qualifications of the animal involved. Many such stories and their sequels–are recorded by tracks in the snow.</td>
<td>Changes in physical nature of water in and near snowbanks may affect the economy of living things that are close to the soil, particularly those that exist far above the soil and its blanket of snow. Management of plant cover is a most important aspect of snow cover planning.</td>
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<td>In Great Lakes region in fall, before snow accumulates, soil may freeze to a depth of 3 feet, and, if covered with snow, may continue frozen through winter. In areas with less snowfall, soil may freeze to depths of over 1 feet. Such conditions limit activities of animals that must burrow.</td>
<td>Anything that anchors a layer of air at a given level may be useful in wildlife management. Forests, grass-covered soils, mulches, cultivated soils, blankets of snow are all factors. The pelt of a fur-bearing is simply a portable blanket that permits its wearer movement denied fixed organisms.</td>
<td>The role of a snow cover in heat insulation is one of the most important performed by winter snowfall influencing not only plants and animals but determining in part the speed of the spring runoff and loss of top soil by erosion, driving wind, and traffic of various kinds.</td>
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Compacting of snow and compacting of soils may affect the water-holding ability and survival needs, must move through farming areas, fields may be rolled in spring partly to concentrate water around seeds. Similarly, paths, trails, and roads followed by man introduce problems into snow cover matter. Ice over ponds may be transparent, permitting light to reach underwater life, which can carry on normal functions. A blanket of opaque snow may change the whole, stopping oxygen production, and permitting overproduction of deadly carbon dioxide, killing most underwater animals. Heavy snowfalls may bend woody plants to the ground, leaving "roofed" areas that may retreat and find shelter, food, and safety. By bending tops of rows into early snowbanks, winterkill may be avoided, but danger of mouse damage may be increased. Man can help here. Snow damage to ornamental trees may be great at times, and carelessly built dwellings, not designed for heavy snow, conditions, may also suffer severely at times. Much trouble can be avoided by use of intelligent and appropriate designs that meet the needs of the locality involved. | Ice over ponds may be transparent, permitting light to reach underwater life, which can carry on normal functions. A blanket of opaque snow may change the whole, stopping oxygen production, and permitting overproduction of deadly carbon dioxide, killing most underwater animals. Heavy snowfalls may bend woody plants to the ground, leaving "roofed" areas that may retreat and find shelter, food, and safety. By bending tops of rows into early snowbanks, winterkill may be avoided, but danger of mouse damage may be increased. Man can help here. Snow damage to ornamental trees may be great at times, and carelessly built dwellings, not designed for heavy snow, conditions, may also suffer severely at times. Much trouble can be avoided by use of intelligent and appropriate designs that meet the needs of the locality involved. |

Managed light may be used to delay or accelerate melting of snow blanket and is more efficient than it would be under better lit conditions. It may also delay thawing, acting as a mulch.
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<thead>
<tr>
<th>FACTORS INVOLVED</th>
<th>DESCRIPTION</th>
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<tr>
<td><strong>Transportation</strong></td>
<td>Snow that has fallen to the ground may remain where it falls; but much of it may sooner or later shift its position because of wind, water movement, animal activity, or gravity. Some of it may be moved because of an unstable base—a floating log, piece of ice, or a moving animal.</td>
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<tr>
<td><strong>Topography and the Snow Cover</strong></td>
<td>Developments in snow cover are influenced profoundly by the topography of supporting ground, as well as by the nature of the blanket itself. Masses of snow seek equilibrium, and if unsupported by the masses of earth upon which they rest, may move until the pressures are adjusted.</td>
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<tr>
<td><strong>Snow in and Above Water</strong></td>
<td>Snow accumulations not only affect activities on earth under snowbanks but also affect conditions in water that is under the accumulations of snow. Such conditions may be at the same time physical and physiological in nature, and they may even be of importance occasionally.</td>
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<tr>
<td><strong>Snow Sculpture</strong></td>
<td>Accumulations of snow are subject to influences that change their shape, density, and other characteristics. By violence, winds may mold the snow surface and the temperature of moving adjacent air may modify the shape of a bank. Animals moving over the surface of a bank may change its shape.</td>
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<tr>
<td><strong>Time and Snow Blankets</strong></td>
<td>Over the United States, the snow blanket annually averages from less than 1 inch to more than 800 inches, the snow lasting from less than a day to more than 150 days. These figures are reasonably consistent, and are within a framework of yearly temperatures between 125°F. and 50°F.</td>
</tr>
<tr>
<td><strong>Extraneous Inorganic Materials</strong></td>
<td>Any long-standing snowbank—like the accumulation of ice in a glacier—has much extraneous inorganic material with it. Material may be soil, slag, dust, mud, or other substances, brought in by wind, flood, or animals. This material has a significant materially and functionally affect the life of a snowbank.</td>
</tr>
<tr>
<td><strong>Extraneous Plant Materials</strong></td>
<td>There is a mutual relationship between plants and the snow blanket. This is true whether it concerns snow in motion or that which has been &quot;fixed&quot;; the plant materials may either be anchored or free. In snow blanket management, shade provided by plants offers planners a most valuable tool.</td>
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<tr>
<td><strong>Problems of Minute Animals on Snow</strong></td>
<td>The 89th and 107th inserts of this series considered this topic in detail. Certain crane flies, stone flies, springtails, the snow fleas, spiders, and other insects are often active during the time that snow covers the ground, and in a minor way they affect other organisms to some degree.</td>
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<td><strong>Problems of Extraneous Large Animals</strong></td>
<td>Large animals find that problems associated with snow cover lie largely in a limitation of movement, in temperature moderation, in ability to get at food supply, and in ability to avoid being seen by enemies. Conditions change with size of the crust and depth of snow accumulation. If the depth of the snow exceeds the length of an animal's legs, it may prevent freedom of movement to escape enemies and to get food, unless burrowing is possible. If weight of the animal, standing or running, can be supported as a non-working mass, the animal, conditions of survival change.</td>
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<td>WILDLIFE ROLE</td>
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<td>Generally, increasing the velocity of the element moving next to a snow accumulation accelerates snow movement, and decreasing the velocity slows such movement. Knowing this, we can anchor snow over soils that should not be frozen, or build temporary snows in areas needing water reserves.</td>
<td>Snow and ice crystals moving in air or water may have an abrasive effect on stationary objects, while snow in a fixed position may prevent such action from occurring. In some locations, snow may well be considered of significance we argued these effects during the whole of the calendar year.</td>
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<td>Animals, including man, may sometimes start avalanches by upsetting established balances, and may be destroyed by the violence of resulting disturbances. Whole communities of animals and men may thus be destroyed by slipping snow cover, but established woods may lessen danger.</td>
<td>Procedures recognized as of value in preventing soil erosion may be suggestive of those valuable in preventing damage by slipping snow cover. Highways, railroads, and they prevail and whole communities may be destroyed by snow slides. Miniature slides may be observed on roofs.</td>
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<td>Snow over waterways of fluctuating level may provide sanctuary for animals like mink, which can feed in safety on animals in distress. Even water running over normally dry earth — but under snowbanks — may create, in spring, a new, if temporary, world with its special problems.</td>
<td>The abrasive effect of snow and ice-clogged moving water may scour creek bottoms of plant and animal matter, freeing many small animals into the water to become prey for fish life. Such abrasion may also help to shape the stream bottoms and even slowly widen and deepen a waterway.</td>
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<td>Heat from decaying organic material may melt a snowbank from beneath; warm air arising from a mouse's nest may melt a chimney of snow through a two-foot snow bank. A herd of deer may, by moving about, pack down snow to form an open shelter, with its attendant advantages and hazards.</td>
<td>The maintenance of open highways for commerce and pleasure involves the sculpting of snow in a large way. The management of snow on rooftops may involve a number of ingenious techniques. Still chiefly used, however, is the old-fashioned, but quite effective, traditional snow shovel.</td>
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<td>Even in regions experiencing the greatest extremes of temperature and snowfall, vegetation is seen on or near the snow. This is obvious near cities and dusty fields. The snow near a coal-burning community differs greatly from that of the open country, and may be an index to air purity.</td>
<td>Freezing conditions may be necessary for the completion of the life cycle in some plants. They provide an ideal background for many animals to reproduce and prosper. The seeds of a large number of plants will not germinate unless they have been subjected to freezing.</td>
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<td>All life is affected by the purity of the air with which it is associated, and snow brings a more pure atmosphere. The air This is obvious near the snow. The air This is obvious near cities and dusty fields. The snow near a coal-burning community differs greatly from that of the open country, and may be an index to air purity.</td>
<td>Downdraft from bare dusty fields, the snow may appear muddy because of the windblown material accumulating there. This may provide an indication of snowbank anchoring qualities in preventing undesirable wind erosion. Mutual movement of snow and inorganic materials are important.</td>
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<td>Animals profit by an accumulation of snow if they can burrow in it, as do mice. Plants provide a source of food for such animals, and the snow cover provides shelter from enemies. The way in which snow melts around the trunks of trees shows a definite relationship between snow and plants.</td>
<td>Surface snows are commonly bearers of such seeds and fruits as may be blown about during winter, and thus help in distribution. Particularly conspicuous may be the seeds and fruits of ash, hawthorn, branch, maple, and weeds, like Russian thistle, ivy, and similar winter bird-food plants.</td>
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<tr>
<td>Moreover snow may provide a food supply for some birds. Plants provide a source of food for such animals, and the snow cover provides shelter from enemies. The way in which snow melts around the trunks of trees shows a definite relationship between snow and plants.</td>
<td>Some snow fleas are dark, and the heat they absorb makes possible a remarkable existence in which they are frozen in the snow at night and become active when warmed by the day's sun. They may require special bodies, rather than through lungs, and may feed on pollen and plant material.</td>
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<td>Prolonged snow following the last snowfall may provide a food supply of some birds. Plants provide a source of food for such animals, and the snow cover provides shelter from enemies. The way in which snow melts around the trunks of trees shows a definite relationship between snow and plants.</td>
<td>Snow accumulation provide an important food supply for nesting birds and foraging snow (e.g., piper free from enemies. Fortunately, when spring snow melts, rapidly feeding snowstorms occur. Spring snow storms occur. Snowstorms occur, and many small birds are snow-covered animals.</td>
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nature IN THE SCHOOL

The programs and textbooks used in our schools today seem to attach little significance to such simple phenomena as snow blankets, which can “make or break” the farmer, the merchant, and many others.

Every year millions of people see the snowdrifts appear and disappear, without realizing that they are witnessing the operation of the natural water cycle—the sequence in which water vapor is precipitated to earth in liquid or solid form, only to be returned directly or indirectly to the atmosphere as water vapor.

It might be interesting to find out what results could be obtained from tables bearing on the relation between snowfall and local temperatures. Such tables need not be highly accurate to be reasonably significant. The student might make a chart consisting of eight steps, each representing a unit of five degrees—from zero to thirty-five degrees above zero, Fahrenheit. Use a stick, marked in inches, placed vertically in the ground in a sheltered place. Indicate on the chart the number of inches of snow accumulating at the different temperatures.

Does it seem that the heaviest snowfalls take place near zero, or near the freezing point of water? Are the big local snowfalls in the dead of winter, in the fall, or in the spring? Is there a basis for the saying that “it may be too cold to snow?”

Chart the temperatures of a number of snowbanks from measurements in the air just above the surface of the bank; at a point just beneath the crust; at a point a foot or more beneath the surface; and close to the ground under the snow. Try to explain the differences that may be noted during the operation. If there is a crust on the snow, and the sun is shining, is the snow under the crust ever warmer than the air above it?

How much difference in temperature can you find in one vertical inch of snow near the surface of the bank? Such a difference conceivably could have a bearing on a practical problem. If your airplane, for instance, came down for a crash-landing on a windswept glacier, would you be better off to stay in the unheated plane, or would it be more prudent to burrow into a snowdrift?

Using strips of cardboard a foot wide and a yard long, see if you can make a snowdrift form when the wind is blowing the snow. In competition with others, try to make a drift cover a marker a foot square when the marker is lying flat on the snow. The usefulness of an object in anchoring moving snow is important if the water to be released later is to be conserved.

Place a number of foot-square markers on the snow, and hold them in position with weights. Try markers of several different colors, to see if color in any way affects the manner or the speed with which the markers melt their way into a snowdrift.

The top of the snow cover, at certain times of year, may be sprinkled with the seeds and fruits of trees and other plants. Measure the distance from some of these seeds to the nearest plant that bears similar seeds or fruits. Notice whether a good snow crust helps or hinders the movement of plant parts, or if it helps seed dissemination in some respects and hinders it in others. Which kind of seeds or fruits are found farthest from the plants that bore them? Try to find some seed-bearing plant parts that move like “tumbleweeds,” others that move because they are winged, and still others that are blown like dust over the crust of the snow.

Make a record of the bird and mammal tracks found on the surface of a snowbank, and try to interpret the actions of the creature at the time the tracks were made. Note the degree to which larger and smaller animals can move across the snow crust without breaking through. Small-footed, heavy deer may have difficulty in the search for food or safety in the deep snow, while a relatively large-footed animal, such as a rabbit, moves across the snow with ease.

Find a place where a bird or mammal has burrowed into a snowbank, and explore the trail under the bank by moving the snow back. Does the trail of a mouse under a snowbank lead to a food supply? Is it likely that such an animal lives in a world of constant danger? An observant student needs no textbook to find the answers to such questions.

In a field partly covered with snow, try to determine how deeply the topsoil is frozen, and whether there is a variation in the depth of freezing between snow-covered and bare topsoil. On the basis of your findings, how does a snowbank help to protect plants?

Notice how frequently heavy snows bend down the branches of trees and shrubs, so that they form roofed areas in which birds and mammals may find shelter from severe weather conditions. What local animals are most likely to be benefited by such shelters? Do animals finding shelter in such areas ever feed on the bark of the plants that provide them with welcome shelter?

Make a snow house, or igloo, as suggested in the accompanying illustration, and test the temperature both inside and in the open air. Try sleeping at least one night in a properly constructed snow house in order to test its comfort. In making practical use of the snow blanket, the student will better appreciate the part it plays not only in his life, but in the lives of the animals and plants around him.

Igloo blocks are 18 inches long, 12 inches wide, and 6 inches thick, made by trampling snow until hard. Place blocks in a circle 5 feet across, leaning them to the center. Cut first four to slope, and on them start second layer from inside the house. Water will pack ice hard. As the igloo grows, make an entrance, which can be protected by a tunnel of blocks. Entrance should be below floor level, thus forming a thermal trap that prevents loss of warm air and admission of cold.
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Silk threads of a cocoon, seen under the light microscope magnified some 45 times, resemble a curtain of gauze. The regularity of the thickness of the fiber is one remarkable feature, as is the weaving of parallel threads in bundles.
The most wonderful spectacle that human eyes can behold is the starry sky at night, yet the realm of the infinitely vast is only a part of the cosmos. In reality, the whole prodigious universe is made up of the infinitely small, composed of entities so minute as to be invisible.

Man seems set midway between the infinitely small and the infinitely great, so that the adventures awaiting explorers of the microcosm are at least as rich in promise as those that lure astronomers on. Thirty years ago, scientists would hardly have dared to hope that they would ever see those collections of atoms called molecules; yet today we can see not only molecules, but even the tracks of atoms and of subatomic particles.

The photographs on these pages have been organized in a series of "steps," starting with larger objects and moving down to the microscopic and ultramicroscopic. In terms of units of measurement, they range from millimeters through microns to angstrom units, the latter named after the nineteenth-century Swedish physicist. Bacteria and metal crystals are of varying sizes round about the micron mark; viruses, on the other hand, are from one-tenth to one-hundredth that size in the case of animal viruses and one-thousandth in the case of vegetable viruses, which are measured in angstroms. Macromolecules, bundles of millions of atoms, tend to be smaller yet. The objects seen on this and the opposite page are relatively large, their magnifications ranging from about 50 times in the case of the cocoon threads at left to 4,500 for the zinc sulphide at right. As we move closer toward the atomic level, on the following pages, objects are shown in a series of photographs of increasing magnification.
The present article has been adapted from The Thirteen Steps to the Atom, by Charles-Noel Martin, Dr. Martin, a French physicist, began his studies at the University of Algiers and later took his doctorate at the Sorbonne. He did research at the Institut du Radium under Mme Joliot-Curie, and then, under Louis de Broglie, at the Institut Henri Poincaré. He is well known for both his scientific and popular publications. The Thirteen Steps to the Atom has been published in this country by Franklin Watts, Inc.

Jewel-like material shown here is automobile engine grease magnified 20,000 times. The grease above is still not used.

After use, some of the oleate fibers remain intact, while others have been torn, making lubrication less effective.

Particle of DNA (deoxyribonucleic acid) is like a radian sun. DNA is a huge molecule consisting of chains of simple
Recurrent fever microbes can be seen in light microscope, but reveal details only under electron instrument, as above.

Fibril paper, magnified 7500 times, includes diagonal cellulose fiber of original wood from which paper was made.
Bacteriophage viruses are seen clinging by their tails to the outer membrane of the white bacteria they are devouring.

Surface crystals of molybdenum oxide are shown magnified over 60,000 times. Impurities break up geometric pattern.

Tobacco mosaic virus is magnified 94,000 times. Unlike T-shaped bacteriophage, it has the form of a hexagonal rod.

The power of an instrument to distinguish small details is called its resolving power. With the conventional light microscope, the limit of resolution is the smallest distance apart at which it is possible to distinguish two specks of light on a specimen. But the two specks of light are in fact two sources from which trains of light waves are emitted toward the eye of the observer, and for this reason optical microscopes cease to be able to distinguish details the dimensions of which are comparable to the length of light waves. For such very minute studies, the electron microscope is used instead.

In the electron microscope, a beam of electrons is fired at a specimen thin enough to allow the electrons to pass through it with some ease. If some parts of the specimen are thicker or denser than others, and thus more able to stop electrons, there will be variations in the proportion of an electron beam transmitted through different parts of the specimen. A photographic plate or a fluorescent screen placed behind the specimen records these variations. The superiority of the electron microscope over the optical instrument lies essentially in the fact that the wave length associated with a beam of fast electrons is far less than that of visible light, thus extending the possibilities of research concerning more minute objects.

The photographs on these two pages and the preceding two are examples of the magnifications to be obtained with new techniques. They range from a mere 7,600 times in the photographic paper seen on page 51 to 700,000 times for the particles of gold dust shown at right. Among the largest objects is the crystal of molybdenum oxide on the left, seen at some seven hundred times the magnification of the salicylic acid crystals on page 49. Of living forms, the dominant ones are the bacteria — about the same size as metal crystals, except in the lower ranges, which are smaller — and the viruses. Bacteria are visible under the light microscope, although their inner structure can only be seen clearly under an electron microscope. As for the viruses, in size they are to bacteria what bacteria are to large animals. Completely invisible under the light microscope, they fall into three types: the vegetable viruses; animal viruses, which are larger and more complex; and finally bacteriophages or T viruses, so called from their shape. The smallest objects represented here are the giant molecules, clusters of atoms numbering anything from around a hundred to over a million. These macromolecules also fall into three types: cellulose, which is the framework of vegetable matter but cannot be assimilated by man; protein, chemically the most important part of living matter; and, finally, molecules of DNA, which carry the hereditary characteristics of living species.
Near atomic particles of gold are magnified over 700,000 times in this photograph. Each grain of this extremely fine gold dust has only a few hundred or a few thousand atoms of gold, and is thus classed on the level of macromolecules.
SAILORS’ SIREN

The dugong, rare marine mammal, gave rise to mermaid myth

By Joseph Curtis Moore

The similarity of location between the dugong’s two nipples and man’s must have inspired the earliest sailors of tropical waters to infer a likeness between the anterior half of the mermaid—actually, a female dugong—and woman. The animal’s possession of a supposedly fishlike (really more whalelike) tail for propulsion would have fostered the further allegation that the posterior half of the mermaid was fish. All of this myth-making is very reasonable, but it is the writer’s opinion—and the reader may feel free to disagree after examination of these photographs—that the further allegation of mermaid beauty has been possible to maintain only because, or where, the dugong has been an infrequent visitor.

The dugong is a sea cow that inhabits the shallow tropical and subtropical bays and lagoons of the Indian Ocean and the western Pacific Ocean, feeding upon the green grasses of these marine pastures. Being a mammal, it has some hair—scattered singly over most of the body—and possesses lungs, which it must refill with air by rising to the surface. The female gives milk to its single young, which is born alive under water and must swim to the surface for its very first breath of air.

Dugong meat is considered very good to eat, its oil excels other animal oils for use in cooking, and both products extraordinarily resist spoiling—a quality of great importance to man in the Tropics. Sea cows are also defenseless and man’s greediness for their flesh has exceeded his desire to learn how these animals live. In most areas since the advent of science, man has kept dugongs so close to the edge of extinction that it has hardly been possible to study them. However, the Egyptian scientist Gohar, working in the Red Sea where dugongs were thought to be extinct, persisted for a period of thirteen years until he had captured fifteen individuals to examine. In each individual, he found the intestine full of a single, locally abundant, species of sea grass. He says that instead of haphazardly browsing along, as many terrestrial grazing mammals do, the dugong uproots whole plants of sea grass and piles them in stacks. When a number of these heaps are completed, the dugong is presumed to eat them more or less in order. Dr. Gohar speculates that this strange feeding habit may serve the dugong by allowing unwanted or even harmful animal life inhabiting the sea grass to creep out of it.

At the northeast end of the animal’s geographic range, in Formosa, the dugong has received protection by being declared a national monument, although whether any still survive there remains in doubt. One wonders in what tropical maritime land the first successful effort will be made to bring the ecology of this fascinating and valuable sea mammal under study.

A Research Fellow at The American Museum’s Department of Mammalogy, Dr. Moore admires marine mammals.
Man Against
the Cold

A visit to the last of the Alakaluf shows their adaptation to a subpolar climate

By Carleton S. Coon

The Gloria is a "barca," sixty feet of stout Chilean pine, as broad and as tough as a Hudson River tug. She has two short, thick masts, a stubby bowsprit, and a galley smokestack that telescopes when under sail. Below decks is a diesel engine that drives her through the turbulent, icy waters of Cape Horn at seven knots, or eleven with the help of sails and a following wind. Approaching the Gloria on the long dock at Punta Arenas, the world's most southerly seaport, the first living thing one hears or sees is Bua, the ship's dog—a tidy Scottish shepherd, friendly to man but unflinching foe to any dog that tries to come aboard.

I boarded the Gloria late in the summer of 1959 as the guest of a group of physiologists headed by Dr. T. H. Hammel, of the University of Pennsylvania Medical School. In co-operation with the Department of Anthropology of the University of Chile at Santiago, Hammel's party of nine was in pursuit of the Alakaluf, a dwindling tribe of Fuegian Indians that possesses an unusual capacity to resist cold weather. Don Alberto Medina and Luis Strozzi, M.D., represented the University of Chile. Per Scholander, from the Scripps Institute of Oceanography at La Jolla, was an old hand at physiological studies, as was K. Lange-Andersen, M.D., from Oslo. Robert V.elsner was present from the University of Washington, Seattle, and Raymond
J. Hock had come from the White Mountain Research Station of the University of California, Fred A. Milner, an anthropologist and physiologist, represented the Arctic Aeron Medical Laboratory at Ladd Air Force Base, Anchorage, Alaska.

Hannel and Elsem, each of whom had prepared up such an expedition independently, had panned forces and assembled our party in Santiago in mid-August. Lange Andersen brought with him from Norway a sort of hand-cranked bicycle that served to test muscular endurance — and many another novel shaped package filled the plane that carried us to Punta Arenas.

Physiologists are gregarious folk who divide up segments of their job just as the organs of the body are divided in their functions. One will handle the rectal thermometers, another will watch a subject's oxygen intake and carbon dioxide output, and a third will check skin temperatures. What each physiologist in our group did on this trip is little known to me.

The trip is a student of physique whose Races of Europe is a classic work of physical anthropology. Now in preparation is his further study, Races of The World (Alfred Knopf).
fared, as well as in preparation for space travel, what a human organism can stand and how he stands it are items of strategic information.

When Magellan passed through the Strait that bears his name, he saw smoke rising from hundreds of fires on and near the shores of the great island to the south and the smaller, fringing islands. Hence the name "Fireland"; Tierra del Fuego. The fuel for these fires was Nothofagus, an evergreen relative of the beech, which throws out great heat. Some of the smoke Magellans spied was leaking out of the roofs and doorways of domed huts, built of a framework of half-hoops covered with the skins of sea lions and sea otters; inside these huts, the temperature was sometimes as high as that of a New York hotel bedroom today. Other wisps of smoke came from the fires burning on clay hearths in skin or bark canoes.

Within the outer periphery of the campfire's radiation squatted a man, his wife (or wives), his children, and several browbeaten dogs. Some of these folk were naked, although smeared with grease and ochre; others wore small robes of sealskin or sea otter skin over their backs. These were the Fuegian Indians.

Before the white men entered and ruined their lives, the Fuegian Indians were divided into four tribes. On the main island of Tierra del Fuego lived a hunting people called the Ona — Selknam in their own language. They killed the native guanaco with bows and arrows, and wore robes of guanaco skin. At the very tip of the main island was a small tribe called Haush; these people disappeared before anyone had a chance to study them, but the Haush were probably related to the Ona. All along the shores of the southern border of Tierra del Fuego and on the neighboring small islands as far south as Cape Horn lived the Yaghan, or Yamana — so-called "Canoe Indians." It was they whom Darwin saw in Beagle Channel; Fuegta Basket and Jemmy Button were Yaghans; and it was among the Yaghans that the Rev. Thomas Bridges devoted his life to his work as a missionary.

The fourth tribe was the Alakaluf — Aveskar in their own language. They inhabited both sides of the Strait of Magellan and the shores of the fiords, channels, and seaways north to
covered with sea lion skin. When they got metal axes they made three-plank canoes and, finally, dugouts. Now the handful of surviving Alakaluf buy their boats from other people.

Until forty years ago, Alakaluf men wore their hair in a soup-bowl bob. Now they have Western-style haircuts. Within the present century, photographs were taken on board ships of Alakaluf men now alive or recently dead, walking about naked. Going naked but for a coat of grease is much healthier in wet weather than wearing someone's castoff jacket and trousers, letting them get soaking wet, and keeping them on in a heated hut. The Alakaluf could stand cold, but not the white man's colds and tuberculosis.

Darwin saw a Fuegian woman suckling a naked baby in a snowstorm, and I have seen naked Fuegian babies walking about in snow. Even today, Alakaluf women habitually go barefoot, wading in 40°F water as they moor and cast off their boats, treating sleet and snow underfoot, and never seeming to mind the cold. Their feet and ankles seem built for this sort of treatment. Short toes; short, broad, square feet with a thick pad of fat on the arch; tubular ankles, three or four inches in diameter: these are designed

The Taito Peninsula, and covered a much larger territory than any of the other tribes. No one knows how many Alakaluf existed at their peak population, but six thousand is the figure sometimes given. The Alakaluf moved about a good deal. Their middens—piles of clam, mussel, and other shells they left at temporary camp sites—are shallow; those left by the Yaghan are deeper, showing that they led a less nomadic life.

Alakaluf, or Alakalup, is a Yaghan word meaning "People who use quartz shells for knives." And so they did. With these shells they carved spear points and harpoon heads out of whalebone, and they also made broad, red spears out of cedar, with which they collected sea urchins. Their houses were originally wooden frames

Unusual swim by water temperature that is barely 8°F above the freezing point.

Alakaluf boy enjoys skin diving with mask brought by party to the Indians.
to equip Alakaluf women for their amphibious, subantarctic lives.

But such observations of gross morphology are too crude for physiologists. They must have temperatures to read, and quanta of gases and liquids to measure in millimeters and cubic centimeters. Hence all the paraphernalia we transshipped from airfield to dock and loaded aboard the Gloria. Such gear is strange to the field anthropologist; all that we need can often be loaded on a single mule. But we cannot study cold adaptation in such a way as to produce conclusive, scientific results. This is a task for a team of physiologists, with boxes full of metal, rubber, plastic, and glass gadgets for their various tests.

Like his crew of five, the Captain of the Gloria was a Chilote. The Chilotes are the inhabitants of the isle of Chiloé, off the southern end of the regularly inhabited coastal plain of Chile, and north of the myriad islands, steep-walled channels, and sea-reaching glaciers of Chile’s almost uninhabited lower coast — the zone we were on our way to visit.

In early conquistador days, a company of noble folk from northern Spain settled in Chiloé, and established the foundation of a special human breed. First, the Spaniards absorbed the local Indians — Chona by name and probably related to the Alakaluf. Later, the product of this mixture absorbed an immigration of Araucanian Indians from the mainland — horsemen, cider-makers, and silversmiths. The result is a new subrace of man: short, square, extremely muscular, black-haired, red-cheeked, energetic, enterprising, and bright. Some Chilotes look enough like Indians for this Mongoloid touch to be noticed, but most do not. Captain Delgado, master of the Gloria, has no Indian features; he looks like a Basque — which probably many generations ago, his Spanish forebears had been.

The Chilotes have had a population explosion. Like Ireland, Chiloé is famous for potatoes, and its waters yield many fish. On a diet of potatoes, fish, and mutton, the Chilotes have bred rapidly, and have exported people. As this human product is cold-resistant, quick, and hard working, it now accounts for the majority of the population in the southern tip of South America, including both Magallanes Province in Chile, and Argentine Patagonia. In the latter, some 400,000 Chilotes retain Chilean citizenship.

The Gloria’s cargo hold, a cavity thirty feet long, twenty feet wide, and some eight feet deep, was to be our quarters for the journey. In it, the day I first went aboard, a gang of carpenters was busy setting in bunks on the

Beach at camp is littered with mussel shells. On slopes in background is a stand of dead Nothofagus trees, to which Indians set fire in the dry season and so can fell without chopping in winter. Tree provides bulk of their firewood.
Our cook's name was Adalberto Carcamo, and we simply called him the \textit{jefe} (chief). A short, fat, red-cheeked Chilote of enormous energy, he came along, he said, just for the pleasure of being on an expedition. He had been on many before. The \textit{jefe} is a rich man, the owner of a bar and restaurant at the foot of the Punta Arenas municipal pier. There he is both a ship's chandler and host to the transient seamen of many nations.

It was on a visit to the \textit{jefe}'s establishment that I saw my first Fuegian Indian, a Yaghan who had come in from Navarino Island as a sailor, Medina, Strozzi, and I bewildered the poor young man with unexpected attention, and he blinked anxiously as the strobes of our cameras flashed. This meeting with a live Yaghan was a thrill I had long awaited, almost as great as when I first saw an Australian aborigine or a Philippine Pygmy.

The second Fuegian I saw was an eleven-year-old Alakaluf girl named Maria Theresa. She had been carried from her island home to a hospital at Punta Arenas, suffering from spinal tuberculosis. In an iron cot she lay, striking her forehead with a clenched fist, slowly, rhythmically, and dramatically, her features drawn into a lugubrious frown. When Dr. Strozzi told her that we would try to see her relatives, her face brightened and her fist unclenched. Her skin was light brown, the palms of her hands were dead white, and the hands large and well muscled, with beautifully formed nails. Her face was broad, her eyes set wide apart, and her features strikingly similar to those of an Ainu girl of the same age I had seen in Hokkaido two years before. Like that Ainu child, she had continuous hair from eyebrows to scalp on either side, and an exceedingly low hairline between. This hairy development left her little visible forehead. Her appearance, unusual for most American Indians, made me even more eager to see as many of the Alakaluf as I possibly could.

The \textit{Glorin} left port on the morning of August 25 and headed south-west in the Straits of Magellan, after a somewhat frenzied ceremony. Captain Delgado had appropriately raised a Chilean flag, and Dr. Lange-Arendsen hoisted a Norwegian flag beside it. As six of the nine expedition members were Americans, something obviously was missing: Don Pedro Arendsen, the honorary Norwegian consul, soon supplied it. The Stars and Stripes took its place with the other national colors at the masthead, and we were off, to the cheers of a small, enthusiastic, and totally unexpected crowd.

At 5:15 P.M. we dropped anchor in...
Bougainville Bay to check a leak in the fuel line. In this sheltered haven, near the tip of the continent, we saw cliffs behind a narrow, pebbly shore, and dense, almost tropical looking vegetation, with the false beech *Nothofagus* and a true cedar (related to the cedar of Lebanon but locally called cypress) as the dominant species, and with shrubs and ferns covering the ground. The scene was not unlike a miniature Japanese garden, exquisitely contrived and then magnified to a majestic scale. Hundreds of cormorants flew about, their speed exaggerated by their rapid wingbeat and craning necks. Among them Hock pointed out a loon.

The oil leak was fixed in short order and we were off again, passing tiny islands with storm-twisted trees, and leaving the snow-covered mountains of Tierra del Fuego in the background. This scenery continued to unfold all the next day until we were nearly exhausted by its beauty.

On the 26th, we passed a manned lighthouse—all the rest are automatic—between Manuel Rodriguez Island and the mainland. The lighthouse keeper waved warmly to us from the roof. A tanker passed us and we saw steamer ducks—those fat birds, incapable of flight, who propel themselves like side-wheel river boats by striking the water with their wings. A condor floated high overhead, and among the gulls glided an albatross.

Before dusk we were visited by porpoises, which made everyone happy because Scholander is a world authority on their physiology and behavior, and he had just completed, in Punta Arenas, a letter to *Science* explaining how these brainy mammals ride, in defiance of dead body physics, on the bow waves of ships. This trick they proceeded to do for us almost as if they knew Scholander was aboard and wanted to entertain him.

At the end of the afternoon, we stopped in a cove to fetch fresh water, and there we found limpets, mussels, mandarin hats, and clams by the thousands, and collected a thousand or so mussels for supper. On the flatter parts of the shore, above high tide, stood the...
channel at a 45° angle. From here on, the navigation became somewhat tricky and Captain Delgado could frequently be seen standing in the bow, where, like a football umpire in a hotly contested game, he passed dramatic arm and hand signals to the man in the wheelhouse.

We arrived at Puerto Eden on Wellington Island, our destination, in the declining light of day on August 29. We anchored in front of the Chilean Air Force house, the only carpenter-built, firm building between the lighthouse we had passed and Rio Baker, a distance of over 625 miles. This house is a two-storied frame structure of about ten rooms, originally built as a hotel for seaplane passengers flying between Santiago and Punta Arenas. Before the hotel was ready for its first guests, the Argentine government had suddenly removed its ban against Chilean planes flying over Patagonia—the ban that had inspired the hotel in the first place. Then Puerto Eden became a Chilean Air Force base and, at the same time, a rallying point and last haven for what was left of the Alakaluf.

Many of these Indians stay at Puerto Eden most of the time, because the Chilean Air Force garrison feeds them when hungry, and gives them as much medical care as it is able. The medical orderly has, for example, eliminated venereal disease among the Alakaluf with penicillin injections. When an Indian needs hospitalization, he is sent...
Laboratory was set up on second floor of the Chilean Air Force building, above, where Dr. Lange-Andersen is seen testing cold tolerance. The subject’s foot is in ice water and thermocouple attached to skin records temperatures.

A constant and interested visitor to station was the so-called “fat girl.” Her fleshy ankles and thick feet are well suited for paddling in icy water. Alakaluf male has typically strong square face with brown eyes and hair.
on the next available ship to Punta Arenas. There is another advantage to his site, too. Puerto Eden is located in the lagoon just south of Angostura Inghesa, the English Narrows. All ships of modest draft that move north through this inland waterway—much calmer than the open Pacific—have to top at Puerto Eden to await high tide, unless they arrive at that exact time. While waiting at anchor, these vessels are invaded by two or three boatloads of Alakaluf, mostly women and children, who swarm aboard to squat, mutely pathetic, by the doors and hatchways. They offer baskets and toy bark canoes (the latter modeled after those of the Yaghan and not their own) in exchange for clothing, food, cigarettes, and forbidden liquor. They also beg when barter fails.

When we first saw Puerto Eden, the beach was covered with molas, shells, and on it were drawn up three or four dugout canoes, old and in poor shape. On the bank behind stood our newly built plank houses, covered with skins and seeping smoke, and behind the most distant house rested fify-odd drums of high octane gasoline. A small, wooden pier reached the channel, and on it stood our reception committee, consisting of three of the outskin of the Chilean Air Force personnel at bases—a corporal, the cook, and the medical orderly. The commander, a sergeant, was in the house, on duty in the station's radio room.

These four men were to be our hosts for a month. To Hammel and his fellow physiologists they turned over most of their quarters, in which work was to go on all night; they installed the jeje in their own kitchen, and let me measure the Alakaluf in their parlor, and never a murmur of discord or a grumble of hurt feelings was heard by any of our party.

Once ashore, we were disappointed to find only five adult males, out of a total population of forty-nine Alakaluf, in the camp. One, Pancho, was ancient and bedridden. Another, who called himself Alessandri after the current president of Chile (he had formerly been Alejandro), had tuberculosis. A third, Enrique, had suffered a crippling injury to one hip and leg in his youth, by falling off a cliff while robbing birds' nests. Only two, Lucho (Luis) Molinari and Jose Lopez, were present and whole. Six other men were off in their longboats hunting sea otters, but exactly where no one knew.

Because these three men, Lucho, Jose, and, in a pinch, Enrique, were not an adequate sample, Hammel immediately applied by radio to the Chilean Navy for permission (duly granted) to search the fiords north of us for the other hunters and to bring them back to Puerto Eden.

Hammel, Elsner, and the other physiologists set up their laboratory in the second story of the Chilean Air Force building. A tent, below, was connected to the lab by tubes and wires run through a window. Their first volunteer was Lucho, for he was needed to guide us to the other hunters. The physiologists' subject spent the night on a cot in the outdoor tent, under a light blanket and with a plastic "space-man" hood over his head, a rectal thermometer in place, and eight thermocouples cemented to various spots on his skin. All night long the observers sat in their second-story laboratory, recording gauges, mixing magic brews, and in general doing things as mysterious to me as to the Alakaluf.

Once they wired Lucho and had him swim for eight minutes in the icy water, recording his internal and external temperatures from instruments on the shore. He came out of the water dripping, but not shivering. Lange-Andersen got all his subjects to grind away on his stationary bicycle, and downstairs I eventually measured all the men except the bedridden Pancho, taking not only weight and the conventional anthropometric constants but also the dimensions needed for calculating skin surface area. Elsner, among other things, measured fat folds on various parts of the body.
Leaving the physiologists at work on the Alakaluf in camp, we boarded the Gloria a few days later and set out northward through the English Narrows into a labyrinth waterway, watching every minute for the otter hunters. Clad in Chilean replicas of Mr. Frost’s Gloucester oilskins, our Alakaluf guide, Lucho, stood like a rubber figurehead throughout the day, scanning the misty waters for any sight of the boats. Each night we anchored in tiny, breathless coves, some still unnamed, but known of old to Captain Delgado. In them we went ashore for water and rowed about in the ship’s boat to shoot ducks.

Everywhere the dense foliage—with ferns and bright red berries under the trees—gave the shore line the look of a doanier Rousseau primitive painting—a look of the Tropics in temperatures only a degree or two above freezing, when not a degree or two below.

Each day, we cruised about a maze of inlets and channels between islands, in waters for which we had no charts. On September 5, we stopped at Vargas Island to pick up a one-eyed, half-Araucanian woodcutter who had been living alone with his dog, cutting “cypress.” As he had spoken to no human being for seven months, he was naturally bubbling over with conversation. He came aboard at 4:30 P.M. and brought us luck. Less than an hour later, we rounded a cape of the same island to see two boats just leaving shingly beach. They held six men, woman, a boy, and nine dogs. Lot cheers rose from the deck of the Gloria and even Lucho smiled.

The otter hunters were wearing good Western clothing, including several pieces of formal attire, and were speaking to each other in Spanish. As soon as they saw Lucho’s beaming face, they shifted Alakaluf. One young man, Carlos, was obviously the leader and all but one of the other men were older. The woman—a small, elegant creature—had curious visage. Her upper face, including her eyes, nose, and cheekbones was small and delicate but her jaw

Dogs accompany men on their hunts for both sea otter and nutria, chasing the animals into rock crevices so they can be speared easily. Like their masters, the dogs seem impervious to the cold water, and often swim to shore.
could not identify. The hunt was over and the men were ready to go home.

We cast them a line and towed them into Rio Baker, the southernmost settlement of the Chilean mainland north of Magallanes Province. Except for Puerto Eden and a few woodcutters’ huts, the intervening stretch is uninhabited. Here we spent the night, bought an ox to add to our meat supply, hung it high, hoisted the two longboats on deck—Lola and the dogs staying in one boat, away from Buá—and we were off, arriving at Puerto Eden with a following wind and tide, on the afternoon of September 7.

Down in the huts—during the next ten days—Medina and Strozzi and I, when I was able to join them, collected an Alakaluf vocabulary from various informants, particularly from Alessandri and from Margherita Canales, a one-eyed, middle-aged woman of great presence and charm, who sang ancient love songs for our tape recorders. Had we given them liquor, I was told, they might have forgotten the dreary present enough to have performed their ancient dances, imitating various birds and sea mammals with startling fidelity. But liquor is forbidden the Alakaluf by the Chilean government, and all we got was song.

Hidden under skins on hut roof is a carcass of a huemul. Hunting of this rare, local deer is forbidden, but a few are killed each year by Alakaluf. The results of our investigations may be summarized under three headings: physiology, physical anthropology, and cultural anthropology.

Our physiologists found that their subjects are indeed cold-adapted. When they slept with little covering at 0° to 5° C., their metabolic rate remained high throughout the night (their basal metabolism being 150–200 per cent of the Dubois basal metabolic rate for white men of their height and weight). The Alakaluf men not only maintained a normal internal body temperature but also radiated heat through their extremities. White men also lose heat through their extremities but suffer a lowering of core temperature under similar circumstances. Australian aborigines, also studied by Scholander, Hammel, and J. S. Hart of Canada, maintain their core temperatures but lose less heat than either Indians or whites through their extremities because of a heat-transfer from arteries to veins in their upper arms and thighs.

From the physical anthropological point of view, this information indicates that ancestral American Indians, similar to the Alakaluf, could have walked from Asia to Alaska over the Bering land bridge at any time when the sea level was low enough and the

outh, and teeth were very large. Her name was Lola and she had charge of the dogs. The boy of the party was Carlos. The other men were Carlos’ other, Virjilo, Manuel López (José López’ brother), Manuel and Julio Rongo, and Francisco.

These men were younger and more vigorous than their tribesmen at Puerto Eden. Except for Virjilo, they were wearing clothing that new to fit them, instead of stuffs. Their vessels were two new Chiloe longboats, propped by oars, from which rose the stench of ripe sea lion meat and the slightly tainted proteins that I
land bridge climate was comparable to that of present-day Tierra del Fuego. All such Indians would have needed was fire, a crude cutting tool, and the ability to build simple huts. America could have been first invaded at any suitable phase of the Wisconsin glaciation. When it actually was invaded must be settled by archeologists.

Racially the Alakaluf are fully sapiens Mongoloids. Some have heavy brow ridges, large teeth with five- and six-cusped molars, and very large hands, with long ring and shorter index fingers. Most have skins as light as Japanese or brunet Europeans, but they also have blue pigment spots on their backs above the sacrum and on their gums, as well as blue genitals. Their eyes are mostly light brown, their hair dark brown. The women's hair is usually red-brown, and probably bleached through diving. All of the men over twenty-five or so had beards, and some wore mustaches. Enrique had hair on his chest and back, and most of them had hair on their legs. The Alakaluf are about as hairy as the Japanese.

The mean weight of the men is 142 lbs., the mean height, 5' 3". They have big bodies, short necks, long arms, and short legs. Their heads and faces are both long and large. In other words, they look about as the first Indians to reach America could have looked, particularly if a little of what later produced the Ainu was added on the way.

Culturally, there is less to say. Ethnographic field work takes more time than basal metabolism measurements or anthropometry. A report on the trip's cultural findings is Dr. Medina's share of the work. He and Dr. Strozzi collected a vocabulary of many hundreds of words, some of which—like Bushman and Hottentot words and like the neighboring Ona language—are pronounced with clicks.

The Alakaluf have different words for father's father and mother's father, but one word for both grandmothers, which suggests that the grandmothers were sisters or cousins. Who marries whom and who feeds whom—an important point in such food-gathering societies—I do not know, but it was clear that much remarriage took place after widowing and divorce. Confidence of the young was not deemed a virtue. Most deaths were caused either by drowning or by violence.

Of more immediate importance than these meager notes is the fact that the survival of the Alakaluf without mixture depends largely on the future of three young women. One of these was pregnant by a Chilean during our sojourn, while another, Theresa, had left her husband and showed no inclination for further marriage or great hope of reproduction.

Much more serious is the fact that the Alakaluf culture—which cannot I studied in a few short weeks—will soon become extinct. To all intents and purposes, the fine details of this Fuegian culture will die with Alessandri at Margharita Canales—one of whom has tuberculosis and the other one eye.
Sloops in tandem, carrying otter hunters, were towed by Rio Baker, and later hoisted to the deck of the Gloria. Problem for scientists lay in finding large enough number of Alaska otter males to make study measurements significant.
CELESTIAL EVENTS

A listing of astronomical occurrences for the first half of 1961

By K. L. FRANKLIN

JANUARY

January 2: The earth is closest to the sun today, a distance of 91.4 million miles.

January 3: In the early morning hours, the Quadrantid meteor shower makes its annual appearance. A single observer could see about forty meteors an hour at the peak of the shower were it not that the light of the nearly full moon will interfere with the fainter streaks.

January 16: New moon occurs about 4:30 p.m., EST, and about two hours later, the moon is closest to the earth, perigee. This combination will result in exceptionally high and low tides for a few hours.

January 29: Venus is farthest east of the sun today, so will remain in the sky for about three hours after the sun sets, being the Evening Star until April.

FEBRUARY

February 15: A total eclipse of the sun occurs today, the 1st passing across France, northern Italy, Yugoslavia, Romania, and the Crimea, and on into Siberia.

February 16: Jupiter is south of Saturn (by about half a moon’s diameter) in the constellation Sagittarius, both are visible in the eastern sky before dawn, the brighter of the pair being Jupiter. Although they appear very close in the sky, Jupiter is 554 million miles from the earth and Saturn, 1,098 million miles away.

February 22: About 2:30 a.m., EST, the moon occults a star Aldebaran. Since this is during the afternoon, telescopes will be needed to observe the event.

MARCH

March 2: A partial eclipse of the moon noticeably begins at 6:52 a.m., EST, and ends at 10:05 a.m., EST. The moon will have set for much of the eastern United States before this eclipse begins, but Westerners can see a substantial part of the eclipse before moonset.

March 5: Venus is as bright as it will be this season—magnitude -4.3. Only the sun and the moon are brighter.

March 20: Spring begins in the Northern Hemisphere at 3:32 p.m., EST, the same time that Altair begins in the Southern Hemisphere. The sun is directly above the earth’s Equator at a point in the Pacific Ocean about 1,100 miles north of Pitcairn Island.

March 21: About 11 p.m., EST, the moon occults Aldebaran again. The event will be interesting to watch, for if its first magnitude star will seem to vanish instantaneously in the dark eastern limb of the first quarter moon interrupts light rays from the star.

APRIL

April 11: Venus, which was so bright in the western sky six weeks ago, is now between the earth and the sun, moving rapidly into the morning sky. At inferior conjunction, Venus is closest to the earth today—29.3 million miles. The nearest that Venus can approach the earth is about 25 million miles.

April 21: Just before midnight, tonight, Mars can be seen appearing as a first magnitude star, about five degrees north of the first quarter moon, in the constellation Gemini. Each month, these two will pass nearer and nearer to each other until July, when observers in Mexico and eastern Asia will see the moon occult the planet.

April 30: At 2 a.m., this morning, much of the east coast of the United States adopts Eastern Daylight Time. Set your clocks ahead one hour.

MAY

May 16: Venus, now the Morning Star, has reached magnitude -4.2, as bright as it will be for sixteen months.

May 21: About an hour after sunset, for the next few evenings, look low into the northwestern sky, above the point where the sun has set. The bright object you will see is elusive Mercury, the planet closest to the sun. After these few evenings, Mercury will gradually fade in the twilight sky. This planet is rarely easy to see and now is a particularly favorable time to make the attempt.

JUNE

June 16: This evening, Uranus—appearing as a sixth magnitude star—can be found about one lunar diameter south of Mars, Bright Mars serves as a useful guide to viewing the first of the outer family of planets to be discovered in our solar system. A telescope or binoculars will be needed to observe Uranus easily. To make certain that you see it, make a map of the scene (illustration, left) and compare it with what you see for several evenings. The object that shifts relative position from night to night is Uranus. A sharp eye on a dark night can see Uranus distinctly, although the planet is over 1.75 billion miles distant from the earth at this time of the year.

Discovered accidentally by Sir William Herschel in 1781, by much the same method of relative motion observation you can use, Uranus was proved to be a planet by a later determination of its orbit around the sun. Deviations from the predicted path aroused suspicions of the existence of a still more distant body disturbing Uranus. As a result of mathematical investigations, this body—Neptune—was found in 1846. Similar deviations in Neptune’s calculated path led to the discovery of Pluto, which has an average distance from the sun of nearly 4 billion miles—in 1930. Thus, Herschel’s keen observations ultimately resulted in a quadrupling of the size of the solar system.

June 21: At 11:30 a.m., EDT, summer arrives in the Northern Hemisphere, and winter takes over the south of the Equator. This is the summer Solstice.

June 23: Mars is less than a degree north of Regulus, the brightest star in the constellation Leo.

Dr. Franklin of the American Museum-Hayden Planetarium prepares this column each six months.
HERE'S HOW TO PRESERVE NATURAL HISTORY

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A frog's voice that sounded like a hammer striking an anvil startled the naturalist, Prince Maximilian de Wied-Neuwied, during a trip one hundred and forty-five years ago to the Fazenda do Agu, near the Rapuniqua River, in the Brazilian province of Espirito Santo. The Prince heard a sound at nightfall coming from a patch near the house in which he was staying. He took his first specimen of the frog some hours later; however, at the Rio das Conchas, in Bahia, as he searched for the new species, *Hyla faber* by its popular name ferrericus, or red-rumped tree frog, he found a nest that he thought peculiar.

Male makes a nest and will battle for it

By Bertha Lutz

...
blacksmith, and illustrated the animal in a demure watercolor.

*Hyla faber*, a tree frog, builds nests for spawning and displays a complex pattern of nuptial behavior involving a rudimentary sense of territory and fighting among the males for nests. Its nests were first discovered in 1893 at Colonia Alpina in Teresópolis, Brazil, by the Swiss naturalists Emil and August Goeldi. They observed the frogs' nests by moonlight, but saw them only when empty or when they contained mated pairs of *Hyla faber*. Emil Goeldi published these observations, but he wrongly attributed the nest-building activities to the female, claiming that the male sat by passively.

An excellent opportunity to observe the activities of *Hyla faber* was afforded the author, her brother Professor Gualter A. Lutz, and their late assistant, Joaquim Venancio, at the

*Açude da Solidão* (Pool of Solitude), situated in a clearing at the edge of the Tijuca forest, outside Rio de Janeiro. A brook forms the pool, which has been dammed at its lower end. The path round the pool has been planted with trees. The spot is protected against depredation and a colony of *Hyla faber* has become established beside the pool.

The nests, built at the edges or in shallows of pools, have raised walls. Perfect nests are rounded, about twelve inches in diameter, and are from two and four-fifths to three and three-fifths inches deep, with a rampart rising two to two and four-fifths inches above water. The male builds them by entering the water, sitting in a shallow place and circling to form a cavity, which he gradually deepens. He builds walls by pushing up clay
Posed on rampart of his finished nesting pan, a male _Hyla faber_ swells throat in song, above, to attract mates. Waiting on rim of nest, male looks at two approaching females, below. He will eventually seize one as a partner.
and patting it on the rampart with his hands. Occasionally he goes under, brings up material on his snout, and adds it to the wall.

When the nest is finished, or sometimes even before, the male stops working and starts singing, from a position inside the nest, on the rampart, or even outside the nest. However, he is always near the nest. His call attracts females ready to spawn, who approach cautiously. They halt now and then in an odd position, sitting on their hind limbs and stretching out their arms. Finally a female enters the nest, swims up behind the male, and, eventually, lays a hand on his back. At first the male keeps calling, then suddenly he turns and seizes his prospective mate about her thorax.

Fights between males were seen several times. They may occur in the nest or outside it. The fighters encircle each other's head and neck with their arms, placing their hands so as to be able to drive their sharp, rudimentary thumbs into the foe. Meanwhile, they may wrestle, using their long legs to try to push each other under while keeping their own nostrils above water. They may thrash round or lie still, with legs drawn up under their inflated bodies; or the stronger or more agile frog may mount his adversary and try to drown him.

While fighting, the frogs may fall from the nest and continue the battle on shore or in the pond, or break off the combat. A fighting pair can be lifted, moved, and examined. One may see the skin round the rudimentary thumb pushed down to bare its curved point. A fighter may have both thumbs dug into his opponent. If one gently lifts the spur out, it is promptly thrust in again. After some handling, the frogs disengage and hop away.

The gravity of spar wounds depends on the parts injured. One dead male taken from the water showed a trickle of blood beside the eardrum. During amplexus, the sexual embrace, the female may be severely hurt by the male's thumbs pushed into her chest as he holds her forcibly. The male repeatedly presses his mate so hard that she is ducked. When coming up, she sometimes brings clay from below and pushes it onto the wall. Our studies indicate this is her one contribution to nest building.

Surface of a nesting pan, above, is dotted with eggs morning after mating. Mating in nest, right, a male grips a female tightly during sexual embrace.
perhaps the most common of nature’s beauties—the snowflake—is the least known. Taken for granted by most people, this delicately and intricately patterned crystal holds a great mystery that has baffled many meteorologists and other scientists. Although considerable research has been done on snowflakes by Ukichiro Nakaya of Japan, Vincent J. Schaefer of Schenectady, New York, and Wilson Alwyn Bentley of Jericho, Vermont, no one has as yet been able to come up with a suitable explanation as to how and why they form.

I have been working with snowflakes for a year and a half now, dating from the first time I saw some snowflakes preserved on a slide and decided to find out how I might go about doing this myself. The directions call for a one per cent solution made with a plastic resin that can be obtained commercially, and used with ethylene dichloride as solvent.

Here is the complete procedure for snowflake collection:

1. Make a one per cent solution by weight of the ethylene dichloride and the resin. Be careful when using ethylene dichloride—it is highly inflammable and its fumes are very poisonous if inhaled.

2. The equipment you will need is: microscope slides; solution; black cardboard; a fine, pointed paintbrush or an eye dropper; and a magnifying glass.

3. It is best if you keep all this equipment in the freezer so that when it does snow you will be prepared and able to collect snowflakes.

4. When snow falls, take equipment outside, preferably to a sheltered porch.

5. Catch snowflakes on the black cardboard. Then use a magnifying glass to determine which ones are the best.

6. Place a drop of cold resin solution on the cold microscope slide. For best results, the drop should be no larger in diameter than is the snowflake itself.

7. Pick up the selected flake carefully with the point of the brush (or eye dropper), which has been previously dipped into the resin solution. This wets it sufficiently to make the flake stick.

8. Deposit the flake flat on the drop of resin on the cold slide.

9. Allow the resin to harden. This will take three to five minutes.

10. Do not breathe on the flake or the slide, for this would melt the flake at once and ruin the specimen.

It is known that snowflakes form at very high altitudes in the clouds. The actual snowflake starts forming when water that is evaporated from the earth’s surface travels to high altitudes and then cools and condenses at very low temperatures, forming a crystalline structure around a very small particle—a nucleus. This nucleus is about five hundred-thousandths of an inch in diameter. Its composition is in dispute. It could be gas, ions, salt, or dirt particles.

The snowflake grows as more water molecules are added to it from the surrounding atmosphere. Finally the flake becomes too heavy for the cloud that contains it. It drops into the lower reaches of the atmosphere, growing larger and heavier until it falls to earth.

The temperature of the air in which a snowflake grows varies, as do the pressure and humidity, but it is usually between 4°C and −40°C. A low pressure with much humidity at a high temperature will produce large wet snowflakes that will tend to clump together as they fall. These clumps (or clusters) may be as large as two inches across. However, high pressure, very hot temperature, and very little humidity will produce tiny snowflakes that are usually in the form of hexagonal plates.

No matter what the conditions are under which snowflakes form, all have six sides and certain characteristics that make it possible for us to classify them. The six main classifications are: hexagonal plates; hexagonal plates with extensions; stellar; ice needles; hexagonal columns; and capped hexagonal columns. Each of these classifications has certain characteristics making it easy to distinguish. Occasionally, a snowflake may form with three, four, or five sides. The reason for this is unknown; it might be compared with the rare formation of a four-leaf clover.

Hexagonal plates are thin, six-side snowflakes made up of water molecules arranged in a lattice pattern. Some have plain surfaces, while others have raised hollow designs that are symmetric (both sides have an identical, corresponding design).

Hexagonal plate extensions are the same plates, but with broad, simple arm that form in the last stages of the snowflakes’ development. These snowflakes usually have a simple, raised design.

Stellar snowflakes have six arms or rays that tend to give them a starlike
appearance. They are found in many different forms—fern-leaved, dendritic, stellar with dendritic plates at the end of the arms, and simple stellar.

Ice needles are slender, hexagonal ice columns with long, sharp, jagged, and irregular points that extend from each end. They often fall during a snowstorm. Hexagonal columns are similar tiny, six-sided prisms of transparent ice, but they are usually flat at both ends and have a long hollow extending from the ends toward the center. They are very light, and sometimes do not fall to the earth but remain aloft in the atmosphere.

Capped hexagonal columns have plates growing at each end and sometimes at the center. The plates all have their own designs and are seldom alike.

There are also other types of snowflakes that fall only under specific atmospheric conditions. Some of these are malformed, rimed, and spatial crystals, powder snow, asymmetrical crystals, raupel, bullets, sleet, and hail.

The pattern a snowflake follows as it grows is determined by temperature, relative humidity, barometric pressure, altitude, the molecular particle around which it forms, and the molecular structure. It is impossible to pinpoint the size and kind of snowflake to any one of these causes. The lattice pattern of structure of the snowflake is very important, but until now there has been no acceptable explanation of the molecular arrangement composing it.

To explain how snowflakes form, we must know what a snowflake is. A snowflake is a crystal of solid water having six sides, a symmetrical design, and a definite structure that is made up of water molecules.

What is a single polar water molecule and how does it affect the structure? The polar water molecule is a molecule of water that is formed when two atoms of hydrogen with an angle of 106° between them combine with an oxygen atom. The angle of 106° tends to make the electrical charges in the molecule balanced. Since the nucleus carries a positive charge and the electrons a negative charge, the side of the molecule on which the hydrogen atoms are located is positively charged and the other, negatively charged. This creates a certain attraction for water molecules to other molecules having a charge (either water molecules or other polar molecules). When the temperature drops, the molecular attraction increases and the polar molecules become more attracted to each other. Since they are all polar in the same way, they form a pattern of attraction—that is, the molecules are attracted to each in a specific way—whereby a definite pattern is formed known as the molecular structure. Once a molecular structure is set up, the snowflake grows with ease by symmetrically adding more and more polar water molecules.

The molecular structure of the snowflake will be different from that of other compounds having polar molecules. One compound, however, does behave like and have a similar structure to snowflakes—this is iodiform, which forms hexagonal crystals at room temperature.

The pattern of attraction of the snowflake seems to be unique. The snowflake grows from a basic hexagon made of twelve polar water molecules that come together. It forms a hexagon because of the alternate combination of the polar water molecules that have their hydrogen atoms in each of two planes.

A minimum of two planes is necessary for the formation of any snow crystal and without planes made up of at least twelve molecules there would be no ice crystal. Additional planes can and are added as the snowflake grows.

However, snowflakes are symmetrical. Hence, for each additional thickness, a plane must form that corresponds to the planes already existing. Additional fin-

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<th>SIX MAIN TYPES OF SNOWFLAKES</th>
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<td>At top, hexagonal plates, plates with extensions, stellar; at bottom, ice needles, hexagonal columns, and capped hexagonal columns.</td>
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WHY doesn't it snow in the Arctic?

Arctic explorers, surveyors, and photographers report that the entire region is often clouded in ice and snow. This is not due to temperature, but to the angle of the sun, which is low in the Arctic sky, and the amount of sunlight reaching the ground.

COMMENTS

There is still much to be learned about the way in which snowflakes form, and about the processes by which they become a combination of crystals that fall to earth. Currently, ambitious studies have accumulated information that helps to classify these latter combinations. Conclusions about the former event are far fewer.

Meteorology—capitalized by most of the other physical sciences—is not favored by a large number of researchers, and the task of forecasting, in itself, limits the amount of time available for basic research. The impression should not be left, however, that there is no concern for uncovering fundamental concepts. A small but capable and productive group of scientists have been working on many aspects of the science. With respect to research on snow crystals, the names of Kepler, Descartes, and Hooke are prominent in early efforts, and more recently the vast collection of over three thousand photomicrographs of snow crystals, described by Bentley and Humphries, is a recognized scientific masterpiece. Dobrowolski published a comprehensive study of snow crystals in 1923, Schaefer, Langmuir, Nakaya, and others continued the investigations.

Miss Dymond has recognized these facts. She has approached the study of snowflake structure in the normal routine of a seasoned investigator: by acquiring specimens in an acceptable manner, by determining as much as possible from their appearance, by reviewing the available literature for reports of the experience of others, and by extrapolating from associated studies of crystal and molecular structure.

The process of snow formation is usually classified as taking place in two distinct stages. The first accounts for the "germ," which is first formed in the upper atmosphere as a result of sublimation of water vapor on a nucleus, or by the spontaneous emergence of the germ as a supercooled droplet. The second is the continuing growth and modification of the germ following its original formation, resulting in the snow crystal proper. The tiny germ, with dimensions of a few hundredths of a millimeter, often possesses observable varieties of crystal shape, but it is the mature snow crystal, grown to a size of several millimeters, that is seen on the ground.

The mature snow crystal has been classified in this student work. The many photographs acquired show patience and craftsmanship-like technique, and support the descriptive material nicely.

The very interesting discussion of the polar water molecule and the part that it plays in the formation of the crystal germ is an attempt to account for the original development of the germ. It is commendable that a fledgling investigator should be willing to study a tiny crystal into a field of theory where experienced scientists have trod but lightly. It is true that there is no universally accepted explanation of the molecular arrangement that must account for the formation of the crystal germ. There have been, however, a number of studies in which the process has been duplicated artificially. For example, the experiments on cloud modification, carried out by Langmuir and Schaefer, were successful attempts to transform supercooled cloud droplets into germs. As a result, some characteristics of the germs and the conditions under which they form are rather well established.

Miss Dymond is to be commended not only for a fine job of accumulating these fragile specimens and evaluating the field, but also for a well-reasoned, original excursion into basic theory.

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This is an enlargement of just the head from the picture of the flying squirrel we ran in the August-September issue of this magazine. We thought you might like to have a closer look at this delightful creature who is really only the size of a mouse. Since this part was only about one-eighth of the 35mm. film frame, it indicates something of the detail Questar will let you see or photograph at thirty feet.

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A BULLFROG AND ITS PREY  Carl Gans

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NATURE AND THE CAMERA  David Linton

COVER: Everyone knows that frogs can and do jump for a variety of reason.
Yet, surprisingly, much of the scientific data on how frogs jump are still eith
controversial or out of date. Ostensibly, the cover picture is simply a remarkable
view of a gape-mouthed bullfrog that has successfully captured some foo.
Actually, it is the result of a happy collaboration—and intensive work—by Merv
F. Roberts, engineer and photographer, and Dr. Carl Gans, engineer and
zoologist. Their research was designed to explore some of the little-known detail
of the function and control of the bullfrog’s “propulsion mechanism”—its method
of aiming at and actually capturing the prey. The discussion of its unusu-
abilities and more of Mr. Roberts’ extraordinary photographs begin on page 2.

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THANKS to the thoughtfulness of the late Miss Augusta S. Kalbfleisch, a ninety-four-acre estate on Long Island has become the Museum’s scientific backyard. Located near Huntington, only forty-seven miles from Manhattan, the Kalbfleisch Field Research Station is already using with various scientific departments’ projects. This latest addition to the Museum’s list of field stations quite unlike any of the others, both in its physical aspects and in the scientific purposes involved. At the Southwest Research Station in Arizona, for example, scientists are five life zones ranging from desert floor to mountain top. At the Lerner Marine Laboratory, at Bimini, Bahamas, they have the whole wide ocean to study. At the Archbold Biological Station, the rich flora and fauna of Florida are at their disposal. The scientists working at those stations may move far afield, but here on Long Island the work is all done right on the property.

Here, long-term projects—involving carefully managed habitats—are already under way. The advantage is that this backyard laboratory is within easy commuting distance. A researcher can set up a project with the knowledge that it is handy and permanent. One even pass their weekends working there. It is a unique establishment and this is how it came about: Miss Kalbfleisch—a woman with a great love for wildlife and birds in particular—had maintained her estate as a bird sanctuary for almost thirty years. Upon her death in 1956, she left the property and a sizable endowment to the Museum. Her will expressed the earnest desire that the estate be used as a bird sanctuary and field station. The property includes a main house, a caretaker’s cottage, a barn, and other outbuildings. Dr. Wesley E. Lanvon, of the Department of Ornithology, is Resident Director.

Some things had to be done right away. The first was to put up a six-foot, chain link fence around the entire property to safeguard outdoor scientific apparatus, to prevent danger by domestic animals, and to keep out hunters. The next step was to prepare a description of the vegetation, along with a map and a land-use history. The latter includes such information as how long various fields have been in fallow, the logging history of the woodlands, and the history of ornamental plantings. Without a management program, the property would gradually return to oak-hickory woodland. The aim, however, is to preserve the different types of cover, while making certain changes. Some weed fields are being sprayed with chemicals to eliminate woody growth; some fields will be burned annually, with the local fire department’s aid. In some selected second-growth woodland areas, certain large trees will be killed and left standing, while other woodland areas will be ground-burned in order to alter the forest litter.

With the management program under way, members of the Museum staff and students began taking a basic inventory of the flora and fauna. Dr. Richard G. Van Gelder went to work on the mammals. Dr. Jack McCormick undertook vegetation studies, and Dr. Richard G. Zweifel made an inventory of the reptiles and amphibians. Apart from these surveys, various special projects already are under way. In two years, Dr. Lanvon has banded almost four thousand birds. Dr. Zweifel has marked more than a hundred Fowler’s toads and Dr. Van Gelder is studying fluctuating mammal populations. Although it is the youngest of the field stations, this backyard laboratory is a busy place. It is necessarily closed to the public because visitors would interfere with the work in progress.

Throughout the area are objects strange to any backyard. Metal posts mark the corners of squares in a grid system covering the entire property. Laboratories house the paraphernalia of modern biology. Dr. Kenneth L. Franklin, Associate Astronomer of the Museum’s Hayden-Planetarium, has set up apparatus for his studies of radiation from Jupiter. Native animals from birds to toads, wear bands or colored markings.

Says Dr. Lanvon: “The property is operating as a field station where our biologists can carry on long-term projects. There has long been a need for such a station within commuting distance of the city. Research is our primary purpose, but many of the things we are doing will provide greater sanctuary for the area’s wildlife.”

An old popular song says, “You’ll see your castle in Spain, through your window pane; back in your own backyard.” With this line beginning on Long Island, we don’t hesitate to look into the future and see the Museum’s backyard laboratory producing all sorts of scientific treasures.

The proper study of mankind," Alexander Pope wrote, "is Man," and this is a sound foundation for the validity of anthropology as a discipline. But sometimes one wonders if the anthropologist is doing the job. There is probably no more and no less disagreement among anthropologists themselves than among any other group of scientists. Yet the anthropologists' disagreements are over such important and vital things as objective and method, not facts alone.

The wide field of anthropology is now legitimately divided into three specialist groups: one group looks at man as a physical entity; another, man as a historical entity; and the third, man as a social entity. In this last group, the conflict of ideals is at times bewildering. The two books under review illustrate this conflict, for they are quite as different as the parts of Africa they concern: the Desert Sahara and the Bush Country and foothills of the Ruwenzori Mountains. Each book sets out with a different objective; each, to a varying extent, succeeds. Their relative importance, then, depends on the value of the objective.

Dr. Briggs sets out to give a general survey of the Sahara's population, and that is what we get. Dr. Winter, on the other hand, sets out to enter the lives of the Bwamba people and to see the world as they see it. As a result, the reader understands one situation well instead of several hundred poorly. Reaching the end of Beyond the Mountains of the Moon, he feels that he has indeed gone far beyond—that he has actually entered the lives of the people and begun to understand not only how they live, but how they think and feel. And, above all, he has the impression that the author is an anthropologist who understands the Popoloculture.

This view may sound jaundiced on the one hand and warmly prejudiced on the other, but there are many things about Tribes of the Sahara to turn one as yellow as the sands. My initial reaction was favorable: having been in the Sahara myself and having once traveled right across it, I responded gladly to the opening lines of the preface: "There has been more balderdash written and repeated about the tribes of the Sahara than about almost any other peoples in the world." The publisher calls Dr. Briggs' research a "field and library work." Yet, to judge from the book, the author might as well never have set foot in the Desert. He often generalizes—with the excuse that no information is available—despite the field opportunities that were at his disposal. For example, he deplores the lack of data on a certain people of considerable interest, a community of blacksmiths living in the Ahaggar. No measurements, no blood analysis of a single one of them, he complains, no description of their social organization or even their kinship terminology, and not a dozen photographs of their faces are available to students. "Why?" he asks. "Simply because the Tuareg are spectacularly romantic whereas the smiths are not."

Then why, one feels entitled to ask, does the author, himself, devote a complete chapter to the Tuareg, instead of spending some of his field time with the smiths? He was evidently in their neighborhood, for he publishes a photograph of the wife of a smith. Why not one of the smith himself?

Throughout this book, one feels exasperated at the fact that here is an intelligent man, a trained observer with an acute eye for detail, one who has traveled extensively in the Sahara, and yet who gives us agonizing details of the terminology used for different types of camel and takes pages to excuse the alledged treachery of the desert nomads in semipyschological terms that amount to no more than a description of the common instinct for self-preservation.

Dr. Briggs raises a topic, then fails to follow through: for instance, he talks of inhabitants of the walled cities of Mzab and one becomes intensely curious about these people, about how they live and think. We are told in detail what they wear, and learn that they average about 5'4" in height. At last, after several pages, we read: "They are set apart from all other Saharan peoples"—and we hope for something significant—"by the fact that their arms are remarkably long although their legs are relatively short. They have narrow shoulders but rather broad hips, and they often become paunchy in middle age." Even if this book were designed for aspiring physical anthropologists, which it is not, this would be pretty meaningless.

For the general reader, it is useless.

Similarly, one learns of the "romantic" Tuareg that they possess 12,000 camels, 2,000 sheep, 20,000 goats, 5,000 donkeys, and 300 head of cattle. In all the author says of their religions that "The Tuareg in general have embraced Islam; but for the most part they are lukewarm and superficial converts."
The book is studded with exceptions of nearly irrelevant detail at meaningless generalization.

It is only fair to say that Dr. Briggs sets out "to make readily available an over-all summary of what is known about the subject." This, in itself, formidable task, as the literature of the Sahara is scattered and unreliable, Dr. Briggs did an excellent job of sorting and has added some fresh information, but anyone seriously interested will probably still have to go to the original sources, while the general reader, hoping to learn what the tribes are like today, is going to be disappointed.

Of a totally different character, Beyond the Mountains of the Moon succeeds exactly where Tribes of the Sahara fails. The task Dr. Winter himself was not an easy one. It is often that few anthropologists, unfortunate, choose to undertake. Instead of combining himself to a vague, over-all survey or even an objective analysis of social structure, the author penetrates to the heart of Amba institutions by investigating the attitudes and feelings of people themselves.

Taking four individuals whom knows, he has persuaded them to tell their life histories in their own words. During the course of their autobiographies—which form the bulk of the book—one gets to know these four people intimately. So intimately, in fact, that a reader may sometimes be shocked, as in Dr. Winter's words, "When one enters [the Amba] universe, it is though one has entered through looking glass." Not only do the situations that confront the Amba differ from the situations that confront us, if they look at their situations in a different way. But through knowing these four living human beings, understanding their problems and seeing how they resolve them, the reader not sees the Amba world as the Amba the selves see it; he also comes to a much broader understanding of tribal life in Africa than the author claims to get.

Dr. Winter opens with an introductory chapter describing the country in which the Amba live, their immediate history, their present economy, and their relationship with neighboring tribes.
By Colin Turnbull

An anthropologist, Mr. Turnbull is the Assistant Curator of African Ethology at The American Museum.

As how far and how little the British missionary has affected their lives outlines the beliefs and customs of those people, particularly the relating marriage and to witchcraft. These are the main topics discussed by the autobiographers.

A young man, Mpuga, is the central character and the first to tell his story—a story of many loves and many wives. This narration is followed by that of two of his wives, and finally a relative who is Amba terms—a brother to Mpuga, but would be his step-father-in-law in our terms. Then come excerpts from a diary Mpuga kept while Dr. Winter was conducting his research, so that we can compare his attitude to the past with his feelings about the present. Dr. Winter ends with a chapter that draws together the four stories.

Each life history has its own special character, but each also has its similarities. All four begin with minute details concerning birth and the events leading to birth, revealing an intense preoccupation with circumstances that would be trivial to us, but which take on hidden significance in the world of the Amba and may be considered as supernatural cause of later misfortunes.

Each story is mainly concerned with the problems of marital life.

In Mpuga, we meet at once a fascinating combination of the old world of Amba and the new. For Mpuga is, among other things, a very Christian person who has had, by his own reckoning, a total of some thirty-six wives. He is a dilemma is one that has considerable bearing on the manifold problems of African people today. They are passing from one world to another, abandoning standards and values for new.

Mpuga became a Christian for several reasons, and we may guess that his stories are shared by many others. He was an ambitious boy who knew that to remain in this new world he had to be able to read and write. For him, Christianity was co-terminous with literacy, so he became a Christian. Also, it was necessary for his family to become a Christian if he was to be respected in his community. For Mpuga, then, the weaving together of a means to education and a man of status.

But Mpuga also tried hard to be a good Christian. He met and married a girl, Lubangi, whose story is the second in the book. She was also Christian and insisted on a Christian wedding, which meant that Mpuga had to get rid of his other wives. He did so, and as the story unfolds we begin to see the conflict; for also necessary to status, in his community, is the possession of many wives.

Eventually he solves the conflict unsatisfactorily by taking as many other wives as he wants, but saying he has only one Christian wife.

In Lubangi's story we see the woman's point of view. She is annoyed with her husband for deceiving her and reverting to polygyny, yet she is sufficiently traditional to accept the situation and even to help cook the marriage meals for her co-wives as they come, one by one. We learn how she likes some and dislikes others. She is not nearly as worried by the problem as her husband, for after all she is still a good Christian—she has only one husband. But she has other problems in common with both the menfolk and the women, and the fear of witchcraft is one of them. In all the accounts we feel this dread constantly behind every little act in the lives of the narrators.

In our world, witchcraft is something irrational, mere superstition. But, for the Amba, witchcraft is essentially practical: it is a means by which they come to terms with the unknown, by which they rationalize those things for which they can see no logical sequence of cause and effect. In the belief that the natural order of events is good, anything that is not good is unnatural and requires explanation. The failure of crops, sickness, and death itself, are all considered unnatural.

We see a bit of this in Dr. Winter's account. We see how a man fears his neighbors more than anyone else; so much so that, if he falls ill, he immedi-
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Amihan pagan ceremony, from Beyond the Mountains of the Moon.
The wood warblers are the favorites of American bird watchers. The United States has 52 species of these useful migrants. Two of them, the Kirtland’s warbler and Bachman’s, are excessively rare. Former warbler nests only in a limited area in the jack pine barrens of north Michigan and winters only in Bahama Islands. Of late, it seems to have become even rarer and has not been seen on its wintering grounds or migration routes in years. Exacting in its requirements, Kirtland’s warblers will only on extensive burned areas are the new-grown pines are no more than a few feet tall. The species is further threatened by an apparent increase in the cowbird, a nest parasite that destroys many warbler eggs and leaves its voracious young to crowd young warblers that may succeed in hatching in the invaded nest.

Kirtland’s warbler, by Harold H. Cratchin Brook Institute of Science, $6.00; 242 pp., illus.

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Kirtland’s warbler, by Harold H. Cratchin Brook Institute of Science, $6.00; 242 pp., illus.

Niko Tinbergren, the eminent naturalist and student of animal behavior, has written a charming book. It will stimulate the incipient naturalist to go out and look; it will encourage the experienced naturalist to extend his observations and to test his theories with field experiments, so well outlined by Tinbergren. Inexperienced and observed observers alike will find more meaning in the relationship of insects and birds among their own species, among other species, and with their physical and biological environment.

The studies cited in the book reflect the history of Tinbergren’s development as a naturalist-scientist, starting with his first experiences as a graduate student in Holland. He covers a trip to the Arctic; his observations on snow buntings; gulls; Alaskan owls; mosquitoes; bees, sand wasps, moths, and his experiments on camouflage and mimicry. Among his more fascinating researches — and, incidentally, his first — are descriptions of the “Bee Hunters of Halltor,” a group of digger wasps who eat honey bees and provide their young with ample supplies of bees while the young develop in burrows. His experiments performed in the field over a long period of time, show how a naturalist determines which cues in the environment are important to the wasp’s recognition of the honey bee and of his own home territory. Exciting, too, is his story of the natural history of the hobbles, great birds of prey with remarkable powers of flight. But when Tinbergren relates his other bird studies, some of his former anthropomorphism creeps into the pages. He tended, in an earlier book, The Herring Gull’s World, to humanize relationships between his birds, using words such as love, marriage, and flitting to describe courtship behavior in the goils. He does not completely succumb to this temptation here, but occasionally he does backslide into the world of anthropomorphic birds.

Many of the general descriptions of terrain and climate in the Arctic, Holland, and England are colorful and evocative; they reflect Tinbergren’s great love of animals and the out of doors. Unfortunately, his style is uneven, his sentences jump from past to present, and sometimes the trend of thought disappears completely and a new one, unannounced, appears in its place. Moreover, his scientific interpretations are single-minded—suggestions of other theories would make the book more useful to the scientist, and also inform the amateur that certain activities may have a number of different, and often contradictory, interpretations.

Evelyn Shaw
The American Museum

ERRATUM

The picture caption for an illustration reprinted from J. D. Carlson’s The World of Feeling in the December, 1960, issue of The American Museum was completely in error. The caption attributed to the daylight blindness of the retinal rods a phenomenon that, instead, is caused by the blind spot (where the optic nerve leaves the eyeball) in the human eye. The editors regret this error and wish to emphasize that the mistake is not the responsibility of either the author or the reviewer.

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Great Horns and High Alps

Saved from extinction, ibexes now abound

By Dieter Burckhardt

As early as the sixteenth and seventeenth centuries, the ibex—proud heraldic animal of many families and communities in the eastern part of the Swiss Alps—had begun to disappear. In 1809, the last known ibex was shot by a hunter in the canton of Wallis in the Western Alps. With this event, Switzerland seemed to have lost forever a characteristic representative of the Alpine fauna. The situation was not much better in other Alpine countries. In the Austrian Alps and in French Alpine regions, the ibex was decimated until the fate of the species depended upon a few animals surviving in the Val d’Aosta, in the Graian Alps of Italy. At the last moment, in 1827, the government of Piedmont proclaimed strict protective measures for these remaining representatives of a species that had inhabited the entire Central European Alpine Zone at least from late Paleolithic times. In 1836, the Italian King Vittorio Emmanuel II, popularly known as re caccitore (the hunter king), became the protector of these last animals. The Gran Paradiso of Aosta was made a royal hunting preserve where 150 gamekeepers saw that the remaining ibexes could breed undisturbed. The king’s successors also protected the rare animals. In 1921, Vittorio Emmanuele II presented the preserve in the Val d’Aosta to the Italian people, founding today’s “Parco Nazionale del Gran Paradiso.” The ibex had been saved. Even though World War II and the postwar period had disastrous consequences for the ibexes in the Gran Paradiso—they decreased from more than 4,000 to less than 400—the colony there, restored to 5,000 animals today, is Europe’s largest, and is the only one preserved under natural conditions. The photographs by Fritz Siedel that illustrate this article were taken in that preserve.

As early as the nineteenth century, attempts were made in Switzerland and elsewhere to start ibex colonies. These efforts failed, however, because it was difficult then to obtain pure-blooded ibexes. Because it was easy to interbreed ibexes and domestic goats, whose offspring proved fertile, ibex-goat hybrids were used in the colonizing experiments. Spiteful critics of the experiments asserted that the hybrids showed the bad traits of both parent species. The fact remains that these efforts were unsuccessful. All these failures, however, did not discourage the ‘ibexes’ friends. At the end of June, 1906, a group of Swiss protectors of nature obtained three four-week-old ibex kids from the Gran Paradiso. In succeeding years, more ibexes were procured from the Val d’Aosta. On June 15, 1909, the females obtained in 1906 had their first young, and by 1911, this small breeding colony numbered eleven head. The time had arrived to put out pure-blooded ibexes in the Swiss Alps.

May 3, 1911, has a special significance in the history of the Swiss League for the Protection of Nature. On that day, a strange procession of nine porters, three gamekeepers, and several noted members of the League and of various governmental authorities, moved into the area of the “Gray Horns” in the Alps of Saint Gallen. Five boxes—weighing from 88 to 167 pounds—were carried up the steep slopes. In them were a three-year-old male ibex, two two-year-old females, and one male and female, both one year old. Finally the group reached its destination and the boxes were opened. Haltingly, the animals took their first steps into the newfound freedom of the Alps.

With touching care, the gamekeepers watched over the fate of the rare animals. Unfortunately, the oldest male and one two-year-old female were unable to adjust to a natural life. They had to be recaptured and taken back to the zoo where they had been raised. Despite these setbacks, the way had been paved for the resettlement of ibexes in the Alps.

Another breeding station for pure-blooded ibexes was established near Interlaken, in the canton of Berne, in 1915. Today, three more breeding stations are in existence. However, the importance of these stations has declined considerably. For several years, wild ibexes—taken from the flourishing colonies at Pil Albris near Pontresina, at the Augstmatthorn above the Lake of Brienz, in the Bernese Oberland, and at Mont Pliureur in the canton of Wallis—have been used to found new colonies. Now, fifty years after the first resettling experiment in the canton of Saint Gallen, all Swiss Alpine cantons possess ibex colonies—with a total of 2,000 animals. The preservation of this remarkable species, which was seriously threatened by imminent extermination a mere 100 years ago, has now been definitely secured.
How could this threat to ibex survival have arisen in the first place? Until recently, man alone was blamed. In the late Middle Ages, indeed, the ibex was regarded as a "roaming pharmacy." Every part of its body—even its excrement—was regarded as having medicinal value. Drugs derived from the ibex were much in demand and brought high prices. To play such a role in folk medicine, however, a species must be rare. Therefore, I believe the medicinal effects ascribed to the ibex—and consequent hunting pressure—were only one of the factors that nearly led to the species' extermination. The ibex was apparently not as widely distributed in the Central European Alpine Zone as the chamois, for instance. Experiences of the past fifty years have shown that the ibex is far more demanding in habitat than is the chamois. Thanks to a generous grant made by the Swiss Endowment for Alpine Research, a thorough investigation of the ibex life cycle is to begin in 1961. From observations to date, however, we may draw the preliminary conclusion that ibexes need much more sun than the chamois and depend, especially in winter, upon steep slopes inclined to the south. Wherever these factors were taken into consideration, resettlement experiments were successful.

The most famous example of such an experiment is the colony in the Swiss National Park in the Lower Engadine. In this area, which was once inhabited by ibexes, seven animals were set free in 1920. The Val Chozza, which was chosen for the resettlement, is characterized by a large stock of chamois; but slopes inclined to the south are lacking in this valley. For this reason, four of the seven animals set free there left the area in 1921. Regrettably, they went to the neighboring Italian Val Livigno, which was then known for its poachers. Two ibexes, both males, were killed. The remaining two, females, migrated southward and reached Swiss territory near Pontresina after traveling about eighteen miles. At Piz Albris they found an area that could not be better for ibexes. Fortunately, the two females were recognized as ibexes by the local gamekeeper, Mr. A. Rauch. Thanks to his persistence, two males—sent from a zoo in 1922—joined the females. Piz Albris is now the largest Swiss ibex colony. More than 250 animals have been captured at Piz Albris during the past five years, to be set free in other areas.

The example of the ibex demonstrates that the preservation and resettlement of animals as large as these in a zone as densely populated and highly industrialized as Central Europe is definitely possible, and can be successful. The story is exciting.
Indeed. It is, however, even more fascinating to observe these animals in the freedom of nature. The environment itself—Alpine meadows strewn with lowers, snow-covered majestic mountains, and awe-inspiring precipices—serves to evoke a unique mood in the tudent of nature.

Looking for ibexes, one must observe slopes and ridges carefully. Even though the animals should be rather conspicuous because of their mighty horns, one is often surprised at how well the ibex, with its fallow, yellowish-gray color, blends into its surroundings. Suddenly one discovers the silhouette of an old male ibex on the horizon. The animal stands motionless against the bright blue sky. Like two Turkish sabers, his horns—nearly a yard long and decorated with large ridges—soar into the air. One may discover five, six, even a dozen of the heavy animals as they lie partly concealed among the steep rocks. Some doze, others chew cud; till others seem content simply to let the sun warm their thick fur.

Any sense of time seems alien to these mighty beasts. One could spend hours watching them. Typical postures of the ibex include stretching all our limbs: resting the chin on a convenient prop; or holding the head up so the sun can shine on the entire neck. Or the heavy head may be supported by resting a massive horn on a rock. An old male may rise slowly, raise his head, and use his long horns to comb his two flanks simultaneously. Then he may scratch himself with the tip of one horn. It is amazing to see how many uses the male has for his horns; support, "comb," scratching instrument, or weapon for beating, pushing, and stabbing.

When the herd comes to life, the plump animals jump to their feet with unexpected agility and present a unique, breathtaking spectacle: in mighty bounds they take flight over steep rocks. Dizziness seems foreign to them. It is inconceivable that their hoofs can find a hold. Rocks loosened by their passage rumble down the mountains, sounding like thunder and arousing still other, unnoticed ibexes. Their flight slows. The animals disappear into a ravine, then emerge on the other side at some towering rock. Now they reach a strip of vegetation that broadens gradually into a meadow covered with lush herbs and grasses. Here the band of fleet-footed ibexes begins to graze.

So far we have talked only about males and it is no accident that only males are shown in the photographs on these pages. Except for the rutting season, which occurs (in areas known to me) from the end of December to mid-January, the old males live isolated from females and the young. They spend the summer in groups of various size, high among mountain crests and ridges. The females and their young spend the summer at somewhat lower altitudes. Immature male and female ibexes remain in the same area as the adult females, but stay in separate herds. Exceptions to this rule are frequent, however.

The strong, almost plump, old males are imposing because of their size and mighty horns. The females appear charming because of their delicate build. Compared to the males, which weigh up to 220 pounds the females weigh a mere 33 pounds normally. Their short, slender, pointed horns are seldom longer than a foot. They also lack the small beard that adorns the old males' chins.

The new-born young are delightful: like little goat kids, they are full of exuberance and mischief. One is always afraid they may break their thin legs when playing. While their mothers chew cud, the kids chase each other. A small rock may be the goal of their leaps; one will hardly reach the top before the next comes and tries to push him down. They are particularly fond of this game if one of
Two male ibexes lie on high ledge in the Gran Paradiso, a national park in the Italian Alps. Profile of the ibex at left shows saber-like sweep of its horns, small beard and strong neck. Ibexes usually favor slopes facing southerly directions.
the mothers plays the role of the rock. Showing no signs of being disturbed, the female allows her young to jump onto her back repeatedly and to climb all over her. Only her head is off limits; but this is the most desirable goal of the young ibexes' climbing tour. Shaking her head, the mother finally chases her young tormentors away.

After a while, the young ones get tired. One after another, they lie down, pressing close to the mother. It is interesting to note that the young ibex always lies behind the mother on her higher side of the slope. One reason may well be the danger of attack by their only large enemy, the golden eagle, which glides noiselessly along mountain slopes. However, the eagle seldom succeeds in taking a young ibex by surprise. Older ibexes are probably too agile to be endangered by the great bird, but they are by no means unconcerned by an eagle's presence. I have often seen an adult male attack a golden eagle and chase it from its perch on a nearby ledge.

Anybody who is not afraid of cold feet and hands and who is familiar with the dangers of the mountain winter will find it worthwhile to watch ibexes during rutting season. At the beginning of the season, the males appear restless. These bulky animals, whose every movement seems determined by sloth, suddenly come to life. They roam the mountains—in groups or singly—in search of females. Their dark, winter fur makes them conspicuous in the snow or against the brown, dry grass. They move at a fast pace or in moderate bounds. When they stop, they can often be seen raising one foreleg, almost like a bird dog, and holding that position for several moments.

The start of the rutting season is indicated not only by the restlessness of the males but also by a characteristic raising of their tails. The top of the tail is laid forward over the back, so that the white underside contrasts sharply with the dark, brownish-gray, body fur. A dark spot on the underside of the tail, indicating the location of glands, is especially conspicuous. Particularly during this season, fights of varying duration occur between
males of roughly equal strength. The fight usually begins with a frontal crossing of the horns, and continues with pushing in various directions. Then one or both males rise on their hind legs (as shown in the photograph on page 101), and the two heads clash noisily. As a rule the rivals separate after a few such exchanges. Once, however, I saw an extremely stubborn fight. In half an hour, two old males thundered their heads together 178 times—in such a manner that from my observation point, more than half a mile away, each blow sounded like the crash of a wooden plank against the surface of a pool of water. Then they separated as if nothing had happened. Frequently, nothing more than a threatening toss of the head is sufficient to chase away a weaker rival.

During this season, the male approaches the female in typical rutting posture: the head is raised in horizontal position, the horns lowered to the rear, and the neck stretched far forward. Frequently, he remains in this position more than an hour, standing behind the female at a distance of from one to two yards. Other suitors wait in a long line behind him. The strongest male stands nearest the female, the next strongest follows and, at the end of the line, one may find some one-year-old males. Seen at a distance, only their posture shows that they are males. This quota of suitors seems to make little impression on the female. When the foremost male becomes too impudent, a female lowers her head and punches his neck or sides with the tips of her thin horns. The male then retires and waits at a respectable distance. In view of the great difference in body size between male and female, its droll to see the ardent male suitor courting much like a henpecked husband.

Shortly before the female is ready to mate, she changes her attitude toward the males. Again and again she flees, followed by the line of suitors. At breathtaking speed, group races across rubble and rock. Over and over again, the female eludes her pursuers by changing the direction of her flight unexpectedly. The old males seem to profit least from these tactics. They are unable to follow the nimble females and young rivals at such a rapid pace.

The herd life of the males during the rutting season and their collective courting differ from the behavior of all other Central European artiodactyls (red deer, roe deer and chamois). This behavior enables the ibex to live during the winter, and even the rutting season, in the limited space of slopes exposed to the sun. Thus, the social behavior of the ibex may indicate an adjustment to its special habitat. Whoever is lucky enough to have a chance to watch the ibex, the freedom of nature will be fascinated by the animals. He will understand why our Paleolithic ancestors immortalized the ibex in their carvings, paintings and sculpture. We may all be grateful to the far-sighted protectors of nature who succeeded in preserving these remarkable Alpine creatures from impending extinction.
FLYING HIS HOrgs to a dilemma, an ibex scratches near the base of his tail with apparent ease. Animal uses horns as grooming instruments as well as weapons, and, if length of horns permits, ibex may comb both flanks simultaneously.
BUSHMEN LEFT RECORDS of their lives in rock paintings such as this from the Mrewa Cave in Southern Rhodesia. At top are trees and rain; below are three running female figures: the first one brandishing a digging stick—and four anim
Physique of A Desert Folk

By Phillip V. Tobias

In the desert wastes of the Kalahari today live a people—known the Bushmen—who are among the strangest of human races. He who venture into southern Africa's hinterland may well stand in wonderment and question before them, hence came these Bushmen? What factors have helped them to remain in so inhospitable a terrain? How does man adapt to life in a desert? Does his bodily structure, his anatomy, change? What of his physiology? How does his functioning of his body? Does that alter, to help him survive? Whatever his bodily structure and function, how does the Bushman's way of life—his culture—alter in adjusting to arid conditions? Is ability to survive in the desert actually a subblend of all these factors? How big does it take to adapt, anatomically, physiologically, and culturally the rigors of desert life? And finally, have the Bushmen been desert dwellers for a long enough period of time to effect many or all of these postulated adjustments? These are the questions we shall explore: perhaps we shall find at least a partial answer to one or two of them.

When Jan van Riebeeck and his crew of Dutch pioneers stepped ashore at the Cape of Good Hope in 1652, they found the land inhabited by little hunters whose speech was marked by clicking sounds, and by emaciated, cattle-owning herdsman, also click-speakers, but with a different language. The hunters came to be known as Bushmen, the herdsman as Hottentots. From the beginning the distinction made between the two was fundamentally a cultural one: the Hottentots differed from the Bushmen in language and way of life. To confuse the picture, groups of the hunters and some of the herdsmen had taken to living along the shores of the subcontinent: they became fused into a third group—the Strandloopers—distinguished from Hottentot and Bushman, as their name betray, by their beachcombing way of life.

Such was the cultural skinwork that bedecked large areas of southern Africa before the arrival of the Bantu-speaking Negroids and the white men—each with their own strange new culture. The racial mélange was even more complex. Were the Bushmen a different race from the Hottentots? If each was a distinct physical type, what was their relation to each other and to the Negroes? How did the Bushmen compare with the other little people of Africa, the Pygmies? And how were all these living groups related to the fossil men whose remains have been found in both South and East Africa?

The problem might have been relatively easy to solve, if a physical anthropologist, equipped with modern knowledge and techniques, had landed from the Goede Hoop with van Riebeeck's stock more than 300 years ago! As it was, by the time a serious study of these peoples began in the twentieth century, the picture had been confused by a history of exterminations, hybridizations, and migrations scarcely, if at all, equalled in any other part of the world. White men arrived in slowly increasing numbers; Bantu-speakers pressed southward in their millennia advance down the east coast of Africa; West African Negroes were imported as slaves, as were Malaysians—adding an exotic, Mongoloid drop to the mixture. Thousands of Bushmen were exterminated for the crime of hunting the strangely peaceful beasts of the white settlers. Hottentots fought Bushmen; white men pursued Hottentots; Hottentots retreated before Bantu; Bantu were in conflict with Whites; and all the while, as by-products of enslavement and conquest, novel experiments in miscegenation were being conducted among the Caucasoid, Mongoloid, Negroid, and Bushmanoid contestants. A whole nascent race, the Cape Colored, was born of this era. Today, that population numbers 1,300,000 and comprises the third largest racial element in South Africa. New tribes—with such names as Bastards and Griquas—were thrown up by these unprecedented mixtures of human genes. Older tribes, like the Gonaqua, were completely annihilated or, like the Korana, brought to the verge of extinction by intertribal warfare. In 1950, for example, there were only three hundred Korana—all that remained of the twenty thousand estimated to have been alive as late as 1850.

In this racial and tribal maelstrom, we can catch glimpses of the Bushman as some sort of living fossil: Paleolithic survivor in a hostile world of metal, farmlands, domestic animals, property rights—and firearms. We see
Huts of early Bushmen were made of saplings covered with sun-dried, closely woven reed mats that kept out the rain.

Hunting gear included spear, quiver, bow and arrows, and a clublike stick.

Short-handled, spearlike weapons with poison on their tips were used by Bushmen to hunt large game and wage war.

him being forced before the combined pressures of Whites, Negroes, and Hottentots into the most arid parts of the subcontinent, those regions of the Kalahari Desert that no one really wanted. So the Bushman, in fairly recent times, became mainly a desert dweller. It is important to remember how recently all this happened, especially when we wish to find out what sort of adaptations desert dwellers undergo.

The Bushmen have long been regarded as a vanishing race. More than thirty years ago, anthropologists were mourning the disappearance of a "few scattered groups still lingering in the Kalahari Desert." "In a few years," wrote Elliott Smith, a leading British anthropologist, "the world will know them no more." In his classic work, The Khoisan Peoples of South Africa (1930), Professor J. Schapera placed the total number of Bushmen in existence "at a conservative minimum" of seven thousand to seventy-five hundred. This figure is still quoted today although, in 1939, Schapera published the greatly increased estimate of thirty thousand. Appearing at the outbreak of World War II, Schapera's 1939 revision did not become widely known. As recently as 1948, the late Sir Arthur Keith estimated that only about six thousand Bushmen still survived.

Current demographic estimates, however, suggest the presence of some thirty-one thousand Bushmen in Bechuanaland Protectorate, twenty thousand in South West Africa and smaller numbers in Angola, Rhodesia, and the Union of South Africa—an estimated total of some fifty-five thousand! The fact that so many are alive today testifies that these little, yellow people must once have swarmed over the face of Africa in numbers hitherto undreamed of and unexpected.

What manner of people are these Bushmen? Anatomically, they constitute one of the most distinctive of human types: so distinctive, in fact, that many scientists have seen in them a peculiar physical form of mankind, resulting from life in the hot desert. Before examining the truth of this view, let me try to paint a word picture of the Bushmen.

They are a short people—the average height of different groups of Bushmen ranging from 4' 9" to 5' 4" in males and 4' 6" to 5' in females. The shortest of them certainly fall into the Pygmy category of stature.

The head and face are unforgettable. Imagine a petite, baby-like visage, with a flat top to the head; a low, vertical or bulging forehead, often with two prominences or "frontal bosses"; smooth brows and slanting eyes, often with Mongol-like eyelids; very low or even flat nasal brisé, with a delicate, slightly elevated tip to the nose; and angular, prominent cheekbones. This is a face with a nearly vertical profile, generally lacking the jutting jaws or prognathism of the Negroid peoples of Africa. Its small jaws house little teeth—usually worn down, even to the gum margins, but seldom showing carious decay. The lips are not thick by African standards. The face's narrow forehead, pointed chin, and projecting cheekbones give it a characteristic diamond shape. The ears are tiny, with a heavily overrolled helix, or margin, if generally without any free lobe. The head hair is highly spiraled. Tufted. Hair on both face and body sparse. The color of the skin is yellowish brown—considerably lighter than that of the Bushman's neighbors, the Negroid tribes of Bantu-speakers.

The pelvic region is marked by appreciable accumulations of fat over the buttocks (steatopygia), or over the thighs (steatomeria). The fat accumulations have been likened to the hump of the camel or the belly of the fat-tailed sheep; the idea has arisen that the accumulations constitute reserve food stores, to be called upon in times of need. Steatopygia has thus been described as an adaptation peculiar to the difficult conditions of life in the desert.

There are reasons for doubting this interpretation. First, rock paintings of Bushman-like figures exhibit unmistakable steatopygia, occupying many lush and well-watered parts of the subcontinent. Clearly, therefore, steatopygia has not been confined...
Animal skins were sun-cured and made into distinctive caps, into women's leg rings and many other decorations.

The fantastic enlargement of the labia minora, known as the "Hottentot apron," is another unusual feature of Bushman female anatomy. No one has suggested this as a desert adaptation; perhaps, here too, sexual selection has played a part. Whatever the explanations may be for these anatomical features, this, then, is a picture of our Bushman, unique in the family of man in Africa. Yet, although so distinctive, the Bushman shows some features in common with the Negro. Blood-group studies, which have proved so useful a tool in the determination of racial affinities, confirm that Bushman blood has many typically African features, while, in other regards, it shows a pattern peculiar to Bushmen. This may suggest that, long ago, Bushman and Negro might have had a common ancestry. It is hard to take this beyond a suggestion at present, because we have virtually no recognizable fossil remains of the ancestors of the Negroes, although we know a good deal about the forebears of the Bushmen.

In most anatomical features differentiating the two groups, the Bushman structure is closer to that of a child. The low, flattened skull; the poor development of his sinuses; his tiny mastoid processes; his bulging or vertical forehead; his small, flat face; the wide distance between his eyes; the flatness of his nasal bridge; the light skin pigment; hairlessness; the short, normally semierect penis with compact, high scrotum: these and many more features suggest that the Bushman has carried into adulthood a number of anatomical features normally associated with the infantile anatomy of any race.

At some stage in the evolution of Bushmen, we therefore assume, changes occurred that resulted in retarding the development of certain bodily structures, without affecting either sexual or mental maturation. Such retention of infantile anatomical features into adulthood is a well-known phenomenon in the animal kingdom, generally known as neoteny. It has been suggested that neoteny was an important factor not only in the transition of an apelike ancestor into...
a member of the family of man but also in the formation of various of the human races in that family.

The advance of genetic knowledge permits us to offer a new explanation of neoteny in terms of gene action. The genes, the material or chemical basis of our biological inheritance, produce their effects by altering processes of embryonic development. Some alterations are qualitative, such as the formation of a new type of pigment; some amend the timing, direction, or speed of a process. A large class of mutant genes either accelerates or retards developmental processes, thus indirectly modifying the ultimate finished product. If the mutant gene operates early in embryonic development, it may affect a variety of developmental processes, and its impact may ramify through many parts of the embryo's body. Hence, instead of postulating one gene for flat nose, another for pentagonal skull, and a third for eye folds, we can visualize clusters of features resulting from relatively few retarding or accelerating mutations. It is suggested that neoteny may be based on such key genes controlling varied developmental processes.

Is it possible that such changes resulted from the adaptation of the Bushman to desert conditions? The late Dr. Robert Broom believed that the Bushman was the "degenerate, stunted descendant" of larger people who had deteriorated under desert conditions. This view does not bear close scrutiny, however. From cave and open burial sites all over southern Africa have come skeletons that are typical of the modern Bushman. These remains have been found over a wide range, far beyond the bounds of the desert regions. In fact, most of them have come from such well-watered regions as the southern Cape forest belt and the Natal uplands. Similar skeletal types can be traced, too, right through Rhodesia to East Africa. Anatomically speaking, then, the Bushman was a Bushman long before he was pushed into the Kalahari Desert.

The fact that the Bushman developed his infantile features before he became a desert dweller rules out the possibility that neoteny in any way
adapted the Bushman to desert life. We cannot even say that neoteny is an adaptation to the hunting and food-gathering way of life, for there are hunters and food-gatherers—the Australian aborigines, for example—who show no infantile anatomical features. Why the development-retarding genes should have been selected in the ancestors of the Bushman remains a mystery. It is difficult to conceive of any especial advantage that neoteny conferred on people in a Pleistocene setting. The Negroes of Africa avoided infantile specializations in a similar setting, yet have flourished over large parts of the continent. Whether there is some subtle tie-up among African climes, trace elements and other food-minerals, retarding and accelerating genes, the secretions of the endocrine glands and the degree of bodily development remains a fascinating and pregnant speculation.

The ancestors of the Bushmen, as the skeletal evidence demonstrates, also underwent a dwarfing process. Infantile structure and small Pymoid stature do not necessarily go hand in hand and some of the ancestors of the Bushmen combined their infantile anatomy with large stature. At different times, it seems, these early Africans underwent two kinds of change—development-retarding changes and growth-retarding changes. The archeological evidence shows that the last step in the formation of the Bushmen was this tendency toward the dwarfing of larger ancestors.

Dwarfing, too, has been regarded as a result of life under desert conditions. Again, this theory is contradicted by the former widespread distribution of Bushmen in some of the most fertile parts of southern Africa.

Late Pleistocene dwarfing in Africa was not confined to man. Dr. M. D. W. Jeffreys has assembled data on a variety of wild and domesticated mammals of which dwarf forms exist today. Examples include pygmy buffalo, antelope, hippopotamus, elephant, dormouse, leopard, and chimpanzee, in addition to dwarf cattle, goats, and sheep. Earlier Pleistocene deposits contain fewer dwarf forms and more giant forms. It is possible that late Pleistocene conditions in
Strange Bushman anatomy—specifically, fat accumulations on buttocks and thighs, above—has been exaggerated as a possible aid in adaptation to the environment. Nineteenth century artist also indicated reputed laziness of Bushmen.

Africa may have favored and strongly selected dwarf forms, and that human dwarfing in Africa may best be viewed against this background.

With dwarfing, as with neoteny, it is possible that the effect was mediated through the pituitary gland. An underactive pituitary during growth and development may result in both infantile features and dwarfed statures. Pituitary midgets, for example, show many infantile anatomical features. What is a sporadic occurrence among Whites, however, is the rule among Bushmen and Pygmies—with the important difference that infantilism in pituitary midgets affects the reproductive system, so that sexual under-development and even sterility commonly occur. Another difference between pituitary stunting and that of the Bushman is that the midget combines infantilism and dwarfing, whereas the ancestors of the Bushman became infantilized before the onset of dwarfing changes. So, although the Bushman's structure superficially resembles that due to an underactive pituitary, clearly a different sort of process is involved. Even steatopygia has been blamed on an out-of-step pituitary, but the curious thing is that steatopygia may develop in a white woman with an overactive pituitary (acromegaly). Even stranger are the bony changes produced in acromegaly: the skull becomes heavy-browed and overgrown, to produce a picture not far from that of Neanderthal man, whose anatomy was poles apart from that of the Bushman.

Here, too, it seems that we would be oversimplifying the picture of Bushman structure if we were to attribute steatopygia to hyperpituitarism. Despite the contradictions, this series of resemblances and contrasts leaves a strong feeling that, somehow, the balance of internal secretions in the Bushman is different from that of other types of man. Recent studies have shown a differentiation between the endocrine pattern in Negroes and that in Whites. Perhaps a fruitful field for future research will be to

Steatopygia is clearly shown in rock paintings from well-watered areas.
TOTTENTS' living patterns resembled those of Bushmen. They, too, downed game with short spears, wore capes made of skin, and carried bows and arrows. Both enjoyed ostrich eggs, and used the empty shells, in net, *left*, to carry water.

...investigate whether the hormonal pattern of the Bushman, in turn, is different and whether such a pattern can explain the specialized features of Bushman anatomy.

Neither the Bushman's Pygmyoid stature, infantile anatomical pattern, nor steatopygia, then, seems to be attributable to adaptation for a desert life. This is not to say that the Bushman shows no anatomical adaptations whatever. J. S. Weiner has shown that the Bushman's body build, as reflected in his height-weight ratio, differs little from that of other African peoples living in hot, though not desertic conditions. People in hot climates tend to have a lower body weight than those in temperate and colder climates. Coupled with this lower weight, a relative increase of body area makes for a much greater cooling surface relative to body weight. This feature the Bushman shares with other Africans. He also shares a broad, low nose, which seems to be correlated with external climatic conditions.

In brief, while the Bushman shows some general African adaptations to hot climates, the very structural features that make him racially distinctive from other Africans are not attributable to desert adaptation. He differs in this respect from the residents of the high Andes, whose response to their environment Marshall Newman has summarized (Natural History, January, 1958).

**G**enetic adaptation is probably a long-term process. Acclimatization, however, is a shorter-term adaptation of the physiological processes within each individual. Preliminary tests show that Bushmen are well acclimatized to high temperature and fairly intense radiation—to both of which their way of life and habitat expose them. Man adapts to heat by an increased volume of sweat, by greater dilution of the sweat to conserve precious salts in the body, by a decrease in the heart rate during activity, and by dilution of the blood. Individual acclimatization applies to white men settling in the Tropics and,
This "mud pack" treatment on the skin is a cultural adaptation that helps the Bushman cope with heat. His technique of water storage, a rainfall is sudden and sporadic earth blossom briefly. The Bushman stores all the water he can in ostrich egg shells and calabashes carefully burying them in the earth against a later day of thirst. Further, as part of his diet, he takes great quantities of water-rich plants such as the fruits of the tasman red (Colocynthis citrullus), the Gemmace cucumber (Colocynthis maura) and other species of plants that assist juicy storage organs.

Another cultural adaptation is him to cope with the cold windy nights of the desert. Experiments carried out by Dr. C. H. Wyndham and his co-workers have shown that there is little difference in the physiological response of Whites and Bushmen exposed to identical conditions in the Kalahari. Culturally, however, the Bushman makes skillful use of his frail hut, his fire, and his skin to create a microclimate about himself. This microclimate proves a measurement to be only a few degrees below the thermo-neutral zone of 30°C, for naked men at rest. Such cultural adaptation carries the Bushman through the cold, wintry nights of the Kalahari Desert.

**Pipe-smoking woman suckles child on her back. Her "tobacco" is probably probably, to Bushmen as well. Such internal adjustments, which affect the individual's body during his lifetime, help Bushmen to cope with hot conditions in the Kalahari.

There is yet a third means of adaptation available to man: he is able to undergo cultural "acclimatization," and adapt his way of life to the conditions of his environment. This process is far swifter and simpler for resourceful man than either the random and long-term process of genetic adaptation or shorter-term, physiological adaptations. Man's plastic culture enables him to don fur-lined clothes and to heat his dwellings in cold climates; he does not need to grow a hairy skin to survive an ice age! Indeed, man's biological evolution has, in large measure, given way to cultural evolution. No longer is he the victim of his physical milieu: more and more is he able to control his environment and, especially, those parts of it that formerly dictated the direction of evolutionary change.

A few examples will show how the Bushman has adapted his pattern of existence to his historically recent way of life as a refugee in the desert. To protect himself from undue absorption of solar radiation and from the desiccating effects of hot, dry winds, he coats his skin with animal fat or blood and accumulates a crust of Kalahari sand on the surface. This protective mail assists his physiological adjustments to extremely hot conditions. So thick and dark may this layer be that the unwary observer doubts, at first, that the Bushman is as light in skin color as reported. A vigorous cleansing of a small area necessary before the anthropologist can attempt to read the true skin color.

**Dr. Torres is with the University of the Witwatersrand in Johannesburg, South Africa, as head of its Anatomy Department. He has helped organize eight expeditions to study Bushmen.**
Cheeks, taper to pointed chin, give Bushman's face classic, triangular configuration. This portrait of "A Bosjesman in Armour" appeared in a travel book written by English explorer John Barrow, published in early 1800's.
A Bullfrog and Its Prey

A look at the biomechanics of jumping

By Carl Gans

The frog has the unenviable distinction of being one of the most commonly used laboratory animals. Hundreds of manuals and dissection guides testify to its popularity, and hundreds of thousands of research papers investigate it. In spite of the frog's popularity, however, there is only a handful of scattered items dealing with its most characteristic attribute—its jump.

The photographs of Rana catesbeiana—the common bullfrog—accompanying this article are thus of particular interest, since they represent a concerted attempt to record such jumps at prey with modern photographic techniques. They are the work of Mervin F. Roberts, a civil engineer and an amateur frog fancier, although he can hardly be called an amateur photographer.

Bullfrogs will jump at "flying" prey from land or water. In order to permit focusing of his camera, Mr. Roberts trained his frogs to jump from a brick on one edge of a tank at bait suspended some ten inches away and four to five inches above the water surface. Best response was obtained when live and moving insects and worms were used as bait. Interestingly, the frogs generally refused to jump in bright light but would usually launch themselves immediately after the lights had been dimmed.

The jump at bait took approximately 0.3 seconds from launch to splash. Ordinary stroboscopic flash units with a flash duration of 1/100th of a second proved insufficient to stop all movement during the critical tongue eversion, and a special unit with a calculated flash duration of 1/10,000th of a second was obtained. The unit was triggered when the moving frog passed the light beam that led to a photoelectric cell.
Jaw is open before frog's tongue, attached behind tip of jaw, is exerted, as is demonstrated by two frogs jumping simultaneously. Apparent in near frog is the way in which hind legs can be twisted to influence the jump direction.
SUSPENSION of the bait caused some initial difficulty. Live animals had to be held firmly, yet be easy to remove. The suspension had to keep the bait from swinging out of the range of focus determined by the camera, and at the same time have virtually no inertia at the moment the frog hit the bait. A metal V, located just above the tank and open in the direction of motion, kept the bait from drifting with minor drafts without offering resistance when the frog hit. Pictures taken with the modified setup showed the prey capture did not significantly change the jump path.

It may be useful to say a few words about the animals involved before starting a discussion of the jumping process. The Salientia, or frogs, are a diverse and cosmopolitan order of amphibians. Most live in the tropics or subtropics. Workers recognize five superfamilies, eight families, and some forty subfamilies among the recent species, yet our vocabulary has but three terms for frog types—frog, toad, and tree frog. This, of course, reflects the impoverished frog fauna of England, where our language originated. It is clearly impossible and undesirable to force this arbitrary trifurcation on the multiplicity of frogs. It is just as foolish to think of frogs as representing but three modes of life history. Some frogs lack a protrusive tongue, others prefer a walk to a jump, and many of the suggestions gleaned from these photographs are applicable only to the genus Rana or even to the species R. catesbeiana.

Just as varied as the pure structural characteristics are those aspects of behavior that directly reflect the pressures of the environment. Some arboreal frogs seem to jump at prey only if the continuation of the jump will bring them into contact with another branch or group of leaves. They will often jump at sitting or walking insects, striking them at the same time they grasp the leaf. This suggests the disadvantage of a drop to the forest floor—even though such a drop would easily be survived. Many true toads rarely deign to jump at any flying prey except low-flying, slow-moving forms. The characteristic feeding movement involves a stalk of crawling or walking prey, and ends in an amazingly well-directed tongue-flicking movement. Evidence suggests that toads generally strike at the front end of a crawling worm, perhaps because the swallowing may be easier when the worm is eaten head first. No one seems to have checked whether it is instinct or learning that governs this element of toad behavior.

The nature of the jump is just as distinctive. Many aquatic and terrestrial frogs move in a series of short jumps, particularly when traveling over rough or grassy terrain. They seem able to leap high enough to surmount the densest vegetation, and to do much of their horizontal travel between the grass stems. The more-or-less pointed head apparently helps deflect contact with stems and leaves. Arboreal forms more often combine a walking climb with the standard jump; some characteristically hang with legs partly and symmetrically extended in quite monkey-like poses. Most forms can and do use their limbs alternately under special circumstances, such as when burrowing or pushing their way through densely woven vegetation.

In many cases the maximal jumps are elicited by some sort of avoidance or fright reaction. Every boy knows that the best way of making a frog jump is by touching its rear. Here, again, there are decided differences between forms. Certain species flee toward the nearest water in a continuing series of straight-line jumps. Others progress away from the water, and still others have been observed to jump up a sharply inclined rock wall, and then disappear into crevices. Interesting, too, are a number of species that will suddenly leap at right angles to their previous direction of motion. Most of these jump patterns are instinctive, although aspects thereof may perhaps be modified by learning.

The change from a walking to a jumping method of locomotion probably represents the fundamental functional shift in the development of a "froglike" animal. All other changes probably came later.

Progression by walking is derived with some modification from an alternating or undulating mode of progression, which is probably the basic and most fundamental swimming movement. The elongate body is thrown into an $S$-curve by the asymmetric contraction of the trunk muscles on the inside of each $S$-bend. Forward movement is caused when forces exerted on the rear surface of the loops pass backward along the body. When the body is immersed, these forces are exerted against the water; on land, the push is against surface irregularities. Where fins are present and used with the motion, they will be moved alternately on the front and rear of opposite sides (left-front, right-rear, right-front, left-rear). There is some evidence that this pattern is primitive, since alternate motion can be produced by activating the limb muscles at the time the contraction waves of the body muscles reach the limbs point of insertion. The nerves to supply the motor stimulation of the limbs are modified from the nerves that activate the trunk muscles to the level where the limb originated.

When such a tetrapod moves slowly, it has three feet in contact with the ground and the fourth in motion. As the velocity of travel rises diagonally placed pair of limbs move simultaneously. This leaves only two feet on the ground, and the position of the body is kept in a kind of dynamic equilibrium by its inertia, the same manner, a runner’s body will continue along a more or less even path with alternating assistance from his two pumping legs. Such undulatory motion is often facilitated by elongation of the body and tail. This acts to extend the distance along which the $S$-curve can act. It also tends to counteract lateral forces, so that the head does not swing too far side to side and returns to the desired line of motion.

The frog’s jump shows a development of a relatively primitive jumping pattern. The animal always starts from the same sitting position. It apparently must resume before each leap. There is little, if any, continuality of motion or elastic pick at the end of each bounce, and one may think of the animal as progressing by a series of standing jumps. The power for propulsion is generated by the simultaneous action of both hind legs. This is the basic departure from the ancestral limb movement.

It is of interest to speculate on the evolutionary origin of this simultaneous movement of the hind limbs.
Jumping movements, produced by a variety of often rather inefficient mechanisms, are commonly noted as escape mechanisms of salamanders and fishes. Jumping combines three advantages: first, a rapid, unpredictable, and hence confusing movement; second, the elimination of a continuous olfactory trail, so that predators hunting by smell have difficulty following the path; third, the confusion of sight-hunters caused by the abrupt cessation of movement. However, some workers—among them Hans Böker, a German student of such matters—suggested that the simultaneous motions of both hind feet drive the body forward in a straight line and facilitate pushing the head, or burrowing, into masses of vegetation. It was felt that this straight motion avoided the swinging movements of the head that might impede penetration.

Although it seems probable that the prefrog stage may have been passed in the water, Böker's argument is weak. Many fishes and salamanders—the eel and sire are spectacular examples—manage to combine an efficient burrowing existence with an indulatory system of locomotion. It seems as logical to assume, for instance, that jumping forms an initial adaptation for a quick return to the water from which the frog had emerged by alternate locomotion. It is unfortunate that we know only a few steps in the complex origin of legs, and that fossil remains seldom permit behavioral decisions.

Once simultaneous movement had been achieved, there must have been a modification of the entire body structure. The tail was no longer needed for propulsion or as a steering organ. There was no longer a premium on elongation of the body, which could now be shortened to the limits imposed by the arrangement of the sacral and trunk musculature. The resulting increase in cross-sectional area—same body volume for less length—was compensated for by additional emphasis on streamlining of the modified animal's head.

Each pair of legs of a quadruped may be thought of as a device for exerting a force against the substratum.
If the body is relatively rigid, there is little advantage in using both pairs for propulsion. Analogously, a car may be equipped with front- or rear-wheel drive, yet both sets of wheels are powered only under exceptional circumstances. Most terrestrial animals are limited because they must use all four legs for support, but aquatic animals can afford to concentrate most of their "drive" in a single pair of limbs. A short-bodied animal has a further advantage, as its drive is set as far to the rear as possible. In most aquatic species of frogs the region that has to exert the push is further concentrated by the development of large webs on the rear feet, supported and reinforced by the digits.

The demands on the swimming apparatus seem to have provided the basic requisites for jumping—a sudden backward push by the hind limbs can project the frog upward and forward on land as well as in the water. However, in jumping it is necessary for a single backward push to produce a maximum of energy; it is no longer feasible to obtain additional velocity by a succession of movements. Therefore, it is not surprising that a variety of devices tends to increase the take-off velocity and to counteract any factor reducing it.

The take-off speed must be attained before the frog's toes have left the ground. Elementary ballistics teaches that the force (F) required to produce a given acceleration (a) in a body of mass (M) is:

\[ F = M \cdot \frac{\Delta v}{\Delta t} \]

and that the acceleration is the difference between the initial velocity \( v_0 \) and the final or take-off velocity \( v_f \) divided by the time \( t \) during which it is exerted, or:

\[ F = M \cdot \frac{v_f - v_0}{t} \]

For a given jump, the mass and the initial and take-off velocities are constant. The force that must be produced by contraction of the leg muscles can only be lessened by increasing the length of time during which it is exerted. This is the same as increasing the length of the initial flight path during which part of the frog retains contact with the ground. The part of the frog in such contact remains stationary until take-off, and then has to accelerate suddenly to full speed at a much higher rate than the rest of the body. The energy for this has to be furnished by the inertia of the frog's body, and the frog's velocity consequently must be reduced. Hence, the lower the mass of the terminal parts, the less the over-all reduction in velocity. The continuous attenuation of the frog's hind legs, down to the thin and elongate toes, is admirably fitted to this requirement.

When frog sits, several sets of long leg bones fold against each other. The elongation and folding of the hind limbs is one characteristic of other jumpers, whether they be grasshoppers, frogs, or kangaroos. The long legs, or the greater the number

In passing from the general problem of jumping to an analysis of M Roberts' photographs of the jump, it is useful to take a quick look at the arrangement of muscles and bones of the bullfrog's hind quarters. The have been diagrammed to emphasize the pertinent points. The diagram (page 31) shows an elongation of a set of bones in the frog's hind leg. These bones are the tibia and the fibula, forming the heel in man and other forms. But here extended half the length of the foot. They articulate with the fused tibia-fibula (sh bones), with the remaining tars; and, through them, with the dig (foot bones). The several sets of leg bones are folded against each other when the frog is sitting. They unfold more or less simultaneously during the jump, and are almost complete unfolded when the toes leave ground.

The elongation and folding of the hind limb is characteristic jumpers, whether they be grasshoppers, frogs, or kangaroos. The long legs, or the greater...
Elongation of leg shows the bone and muscle formation. Muscles on posterior folds, the farther the distance and the longer the time through which the body may be moved while the foot still contacts and exerts a force on the ground. In bullfrogs this distance is greater than the body length, so that a higher acceleration can thus be attained with less muscular stress.

Photographs on pages 28 and 29 show that the process of unfolding occurs neither in the vertical nor in the horizontal, but rather in a plane some 30° from the horizontal. This supports the observation that the main muscle masses of the upper leg lie in front and behind the femur. Both of these major groups contribute energy to the jump. Only a few relatively smaller muscles power the return of the limb to rest.

The frog’s use of two sets of large muscles, apparently antagonistic, for a single sequence of movements is surprising. The voluntary muscles of the vertebrate body are most often arranged in antagonistic pairs. Changes in their relative contraction may move the bones in one direction, in a reverse direction, or hold them stationary. Closer examination shows that the frog’s muscles, though on opposite sides of the same bone, are not actually antagonistic. The first muscle group on the posterior surface of the femur connects the femoral shaft to the posterior plate of the pelvic girdle. Its contraction swings the femur through an arc of some 100°, so that the bone’s free end points back instead of forward. The side photos actually show the bone pointing slightly downward during the jumps. The movement thus provides strong horizontal but little vertical acceleration. The second group of muscles originates on the femur and runs along its anterior surface to insert on a set of flat tendons that attach to the shaft of the tibia. The tendon sheaf runs over the femur’s free end as over a pulley. Contraction of the second group of muscles rotates the tibia-fibula in a direction opposite to that of the femur, thus straightening the leg.

The actual arrangement of the muscles is far more complicated than here described. For instance, some of the muscles lie behind the femur and attach to the tendon over the knee. However, it is apparent that the two groups are opposite in position, but not antagonistic in action.

The pattern of opposite, but not antagonistic, muscles continues down the leg, with muscle systems designed to power the shift of each bone upon the one closer to the body. The leg segments are folded around all joints, except those between tibiale-fibulare and the tarsals and digits. They lie in the resting position and straighten to provide the propulsive force. Between the tibiale and the fibulaire the segments first fold and then straighten around the joint after the animal has left the ground in its jump.

The unfolding of the several segments of the hind leg tends to propel the frog’s body on the same principle as that used by some aboriginal spear throwers. Here the spear is propelled by a separate lever, held by one end and rotated. It is known that in operating a lever, the applied force is to the force exerted as the inverse.
ratio of their distances from the fulcrum (the point about which the lever rotates). But it is also true that the distance traveled by a point on a lever rotating through a given angle increases with the distance of the point from the fulcrum. (During any hour the tip of the minute hand travels much farther on a church clock than on a ladies’ lapel watch.) The diagrams on pages 30 and 31 show that this principle makes for a maximum shift of the body for a minimum movement of the muscles, which are attached very close to the fulcrum.

This seemingly inefficient muscle arrangement has been considered of importance for several reasons. Muscular contraction is not an instantaneous affair—it requires a definite time. However, during the moments before take-off, segments of the frog’s limbs are moving at speeds in excess of six feet per second. A muscle arranged for maximal mechanical advantage would have to contract at least that fast to maintain the continuing pressure of the foot against the ground at that acceleration. It may well be that it is biomechanically simpler to increase the force than the contraction speed of the muscle. A second consideration is the fact that the force exerted by a muscle is reduced when the muscle is allowed to contract for a greater distance. The less the movement, the greater the force exerted. When muscles are attached close to the fulcrum, it is easier to attain the needed force and maintain it through a given angular movement of the bone. All of this should not mask the fact that there may well be reasons of geometry that override aspects of purely mechanical advantage. It is the adaptiveness of the entire organism, and not some special property of an organ, that is normally selected for in an evolutionary process of development.

The four photographs of the jumping sequence show some other ways in which frogs are adapted to efficient jumping. The forearms are folded backward against the body and the eyes are not only closed, but are retracted into the head. The frog can do this without trouble, as it lacks a bony separation between orbital and oral cavities. Both the arm movement and the retraction of the eyes would seem to be behavioral adaptations to jumping. They reduce air friction during the jump and protect these important structures from accidental damage during collision. The side views show the noticeable streamlining during the initial portion of the jump. As the jumping animal levels out, the forearms rotate forward and downward—though it is not yet known whether this motion is triggered by changed inclination or by some other signal.

The closing and retraction of the eyes pose some extremely interesting and as yet unanswered questions. It certainly appears as if the frog first “sees” the prey and then closes its eyes and jumps blind. Such a blind jump would cause the frog to miss a considerable percentage of erratically moving objects. There is evidence, however, that the frog exerts a continuing control over its flight path.

Some of the photographs show a sudden lateral shift of the jump path. (A vertical correction by the frog would be far more difficult to detect and confirm.) This shift or alteration of the path seems to take place fairly close to the prey, and has only been observed when a miss was imminent. After the initial and fortuitous observations were made, it proved possible to increase the frequency of “navigational corrections” by causing the bait to swing just before the frog’s jump. This suggests that the frog may produce the shift by a change in the relative position of its hind legs, which swings the body round the center of gravity. Several remarkable photos (pages 27 and 37) show a frog apparently using the expanded membrane of the right hind foot to swing its body toward the prey.

A complicating factor in explaining this apparent control of the path is produced by the nature of vision in frogs. It has long been known that frogs show remarkably little response to immobile objects. Dead or anesthetized prey is ignored, even when the frog is hungry. A group of biologists from the Massachusetts Institute of Technology recently tapped the frog’s optic nerve and found an explanation. Apparently the frog’s retina does not see or report a mosaic image. Instead, there are groups of cells specialized in such areas as boundary detection. One particular group reacts to the curvature of an object, and may thus be considered to serve for “bug perception.” However, the bug is perceived only if it is mov-
Four-stage jump sequence, above, shows proximity of frog to bait before the mouth opens, and two stages in forward rotation of the tongue. Small vertical rectangle at the left is mirror that triggered photocell as frog passed in front.

Bending of lower jaw, caused by dropping of the symphysial bones, is demonstrated in sequence photograph, below. Also visible is rotating tongue base, and free tongue tip that attains own motion after base has performed full rotation.
ing. Immobility reduces the strength of the "sight signal" to the point where it will be wiped out and not re-instated if the object is momentarily hidden. It is not known whether this cessation of input implies the disappearance of the spatial memory of the object within the brain (if such a thing actually exists in a frog), or how quickly the disappearance might take place. If fading does occur, shutting of the eye might interfere with subsequent modifications of aim.

The closing of the eye would not of itself cut off the image entirely. The lower lid, often called the nictitating membrane, is thick but transparent, and would seem capable of changing the optical qualities of objects seen through it. More important is the fact that the lid undoubtedly cuts down on the amount of binocular vision possible for a frog. Such binocular vision (looking at an object with both eyes simultaneously) is required for the initial aiming. It is not certain whether a bullfrog can start a jump in a direction at an angle to the one in which it is sitting. Many tree frogs can easily do this, but preliminary tests suggest that a directed jump by a tree frog will only be made in the direction in which the head is pointing. This seems to suggest that the aiming process involves some sort of equalization of the stimuli being received from the two eyes. Similar situations have been described in other animals that jump, or project part of their bodies. There is, for instance, evidence that the African chameleon must focus both of its independently operated eyes on an insect at the same angle before there can be assurance of a hit by its tongue.

These various bits of evidence allow a tentative hypothesis for explaining the frog's flight correction. The take-off seems to be aimed visually and then the jump started with the eyes retracted. If the aim remains true, and the object remains in front of the nose, it will not move across the visual field. The reduced binocularity will make the object increasingly less visible as it approaches. However, a faulty jump registers the prey as a moving object on a single eye. The greater the distance between object and flight path, the earlier the moment occurs when the prey is clearly enough "seen" to trigger corrective action. This relationship would explain the last-stage changes in the flight path. It would also be interesting to determine if the frog has any distance—rather than only directional—judgment, or if it jumps at any object of a certain apparent size.

The jump carries the frog to the vicinity of the prey, which, however, must still be caught. The photographs show clearly that the frog does not open its mouth until it is within two to three inches of the bait. It then lifts the head, actually bending it backward on the neck, and drops the lower jaw. The tongue consists of a flat plate with a seemingly small tip on each side of the free edge. Curiously enough, this free edge points backward when the mouth is closed. The tongue is attached just behind the tip of the jaw and the photographs show it swinging forward around the attachment. At its most forward position it will have rotated through 180°. If the aim was right the tongue will reach the prey before rotation is completed. During the forward swing the tongue will elongate and then wrap around the prey, much as the weighted end of a swayed rope will spin around a post. The retraction occurs as quickly, and the tongue carries the wrapped prey into the mouth. The forelimbs may assist in stuffing the ends of large or unwieldy items, but the mouth closes before the frog has traveled two inches.

The speed with which this sim...
process takes place has produced some remarkable confusions regarding its mechanism. Muscles do their work while contracting; they cannot push out only pull. Push is generally exerted by having muscles linked to a rigid structure such as a bone. The labby frog tongue lacks bony support and reaches far beyond the mouth. Thus it cannot be pulled—yet something must move it.

The first anatomical report on the tongue seems to have been published in 1627 by Antoine Dugès, a French anatomist who suggested that the work was done by muscles. However, he apparently lacked proper optical equipment, as his drawings show the smaller structures in the wrong places. Then in 1901 two completely conflicting reports appeared. The first was a detailed study by Gaupp, the man who had earlier revised the standard reference work on frog anatomy. He concluded that there were two sets of muscles, one that flipped the tongue outward and another that retracted it. The second report was a note by Hartog, who seems to have published it twice—in Paris and in London. He claimed that flipping was activated hydraulically by lymph, which filled large spaces within the tongue. He based his case on the amount of space filled and the action produced by the injection into the tongue of molten cocoa butter. One may presume that Hartog soon encountered and accepted Gaupp's study, because a promised longer paper never appeared. In spite of this, and of a careful restudy of yet additional forms by the Indian anatomist Gnanaowthu, and comments on its variation in different groups by the Russian anatomist Tatarinov, there are still many texts that refer to a hydraulically operated tongue. Some have added insult to injury by attributing the theory to Gaupp.

It is not too difficult to prove Hartog wrong. The tongue emerges in 0.05 seconds and is retracted in less time than this—far too quickly to be hydraulically activated. His "large spaces" are artifacts, probably produced by excessive pressure during injection. What, then, is the muscular mechanism that flips the tongue?

Three separate anatomical facts and one well-known biological phenomenon enable the frog to flip its tongue. First is the pressure of a pair of loosely attached bones connecting the tips of the lower jaws. These symphysial bones are unique in frogs, but their true importance does not seem to have been recognized. Second is a stout muscle connecting the ends of the true jaw bones across the tip of the lower jaw. Third is an astonishingly large mass of muscle in the base of the tongue. This mass is attached to the symphysial bones in front and to nothing in particular in back. The posterior and lateral surfaces of the muscle mass are enclosed in a stout covering, but only two relatively small muscles connect the mass to the free portion of the tongue. These are the facts. The phenomenon, namely that muscles become rigid on contraction, is one familiar to every little boy who has demonstrated his inceptile biceps to admiring members of the opposite sex in the schoolyard.

The reconstructed tongue-flipping sequence is as follows: the contraction of the cross muscle, or submentalis, draws the tips of the jaw bones together. This motion forces the symphysial bones downward, and with them the attachment of the large tongue muscle, which now bends in a quarter circle around the contracted submentalis. The simultaneously contracting tongue muscle begins to shorten and assume a straight line. It can do this by letting its "free" end move upward, thus achieving a rotat-
ing motion around the rigid bar of the contracted submentalis. The upward swing of the rigidifying tongue muscle then carries along the body of the tongue, catapulting it forward. The dropping of the lower jaw assists this movement, and the tongue seems to continue traveling by its own inertia. The tongue's elastic structure allows it to stretch so that it is almost twice as long when extended as when resting in the mouth. A second set of more conventionally arranged muscles pulls the tongue back into the mouth, possibly aided by the inertia imparted by the captured insect prey.

**Structure** of frog's mouth is shown at top. When tongue flips forward, the submentalis draws tips of the jaw bones together, and forces symphysial bones downward. Tongue muscle swings up, carrying tongue and catapulting it out.

**Near miss** shows tongue is completely extended at end of jump's aiming point, and body is twisted to correct the aim. Nictitating membrane can be seen over the retracted eye, in contrast to the everted eye of resting frog in water.
The stretching mechanism has the advantage of facilitating the tongue's attachment to prey objects. The tongue is covered with a viscus saliva, and bears a forest of short papillae that would seem to catch on irregularities while wrapping around the prey. Intimate contact with the prey is maintained by inherent elasticity, and before it can unwrap itself the insect or worm will be trapped inside the frog's closed mouth.

It was once thought that the sticky product of certain glands of the upper jaw was wiped off by the tongue as it traveled forward. Guanamuthu had already published his doubts on this point. Now Mr. Roberts’ photographs (page 33) show that the tongue does not touch the roof of the mouth during its forward path. One photograph is again worth pages of discussion.

The tongue-flipping mechanism seems effectively designed to be operated during a jumping sequence. The use of a relatively elastic initial contact with flying prey reduces the chance of sudden shocks on the body. The speed of motion is sufficient to permit the prey to be caught and stuffed into the mouth before the frog hits the water. The bullfrog's size and construction allow it to survive even the most spectacular drop it might encounter normally. It may thus jump freely at any passing prey; the landing can only be more or less happy.

It is hoped that this brief discussion has helped to illustrate that some basic principles of biomechanics may be derived from a consideration of as prosaic an object as jumping and feeding methods of frogs. Many things remain to be learned, even about the commonest animals, and it is obvious that photography can considerably assist the learning process.
Light Reflections in the Winter Sky

Atmospheric phenomena once terrorized awe-struck observers

By Richard G. Beidleman
It had been a chilly night for April throughout the Severn countryside of southern England. As the barley sowers left their homes at dawn to start the planting, the sun, "following its orbit about the earth," rolled slowly up out of the eastern woodlands, bringing with it a never-to-be-forgotten spectacle.

Wild thoughts must have filled the minds of the hundreds of peasants, yeomen, and gentry, who, in the year 1233, viewed the heavens with consternation. In the pale blue sky that reached across toward Normandy, moving in consort with the rising sun, were four celestial spheres of equal brilliance, flanking the sun in pairs. And passing through these paired spheres to circle around the sun were two broad and many-hued, encircling halos. From sunrise until noon, this prodigy rode the spring sky above England, then vanished as mysteriously as it had appeared, leaving bewilderment below.

Through the centuries, many such strange lights have been seen in the sky, ranging from simple halos to complex illuminations that vault the entire heavens, and all of them are associated with the vagaries of light rays in moisture-laden atmosphere. The term "halo" itself was introduced by Aristotle and is generally, though incorrectly, applied to any rings around the sun or moon. Actually, there are two major types of "celestial" rings, differing with respect to their mode of formation.

True halos, most frequently observed in the winter, are caused by sunlight or moonlight refracting from ice crystals that float high in the upper atmosphere. Such rings may have a radius—measured along a great circle arc through the sun or moon—of 22° or, less often, 46°, and on rare occasions 90° (the "halo of Hevelius"). The area within the halo appears darker than the surrounding sky, because no visible refraction of light from the ice crystals occurs there.

What are commonly, and wrongly, called halos in an overcast summer sky are usually coronal rings. Coronas are much smaller than true halos—typically they are only 1° to 5° in radius—and are a result of light diffracting from many tiny water drops of uniform size in a thin cloud. They may occur either singly or appear in sets around the sun or moon. This type of coronal ring is not to be confused with the solar corona, the luminous, gaseous envelope associated with the surface of the sun.

Most often, halos and coronas appear almost colorless. However, both can be colorful sights, especially those seen around the sun. The smaller halos may be vividly red inside, ranging to bluish white toward the outside. The 90° halos have the colors reversed, with blue on the inside. Colored coronas also have the order of the colors reversed. One sort of poorly developed corona, the aureole, ranges in color from an inner bluish white to brown at its outer rim. Rings around the sun are usually less evident than those around the moon, as the sun's brilliance obscures them.

Two halos surround the sun in idealized phenomenon, left. Light reflected from vertical ice prisms cause parhelia to appear flanking sun. Old drawing, above, shows sun's rays being refracted as they strike upon suspended crystals of ice.
Specter of the Brocken, named after a German mountain peak, occasionally appears in the sky opposite the rising or setting sun. Caused by nearly horizontal projection, it casts human shadows on low-lying mists or nearby mountains.
Although it is often not apparent, a halo sky is typically overcast with the finest sort of cloud cover—high cirrus ("mare's tail"), cirro-stratus, or cirro-nebula—in which the ice crystals are suspended. Coronas appear in lower thin cloud cover of suspended water droplets. Ordinarily, halos and coronas do not appear together in the sky, and certainly not in a single cloud, because of the basic difference in the way in which they are formed.

A crude representation of a corona can be attained artificially with simple equipment. To produce such a projected coronal image, take a sheet of glass upon which a fine cover of dust has been permitted to settle, breathe across the glass to coat it with moisture droplets. Project a concentrated light source through this glass plate onto a screen and a colored corona will be clearly visible. The corona also can be seen, without being projected, by looking at a bright point of light through the glass. Similarly, artificial halos can be produced by coating a sheet of glass with alum crystals, and then looking through the uncoated side toward a light source.

There are a number of variations on simple halos, some of which are extremely spectacular. The "psuedhelion," for example, is visible only from aloft. It appears as a reflection of the sun on the upper surface of a horizontal bank of clouds. Again, at daybreak or dusk, the low-lying sun will occasionally project a person's shadow against a distant cloud bank. This enlarged shadow forms what has been called the "specter of the Brocken." An individual who looks at his projected shadow may see a series of from one to five colored rings around the shadow's head, called collectively the "Ulloa circle." These circles are formed, much like coronas, by the diffraction of light rays in the cloud.

The "halo of Bouguer," a ring of about 38° radius hanging in the sky opposite the sun, is another example. Often called a "white rainbow," because, like a rainbow, it appears in the heavens opposite the sun, it is colorless. This halo is also caused by light reflected from ice crystals that are suspended in the atmosphere.

Pillar halos are strange, vertical shafts of light rising above the horizon at night. Associated with neither the sun nor the moon, these are manifestations of our artificially illuminated civilization. On still nights, when flat snow crystals float in the air parallel to the earth's surface, lights from the ground are reflected back by these flat surfaces, causing the shafts to appear. The beams are white or colored, depending upon the original light source on the earth's surface. Some pillars have been seen that measured over 1,000 feet in height—the height, of course, being related to the intensity of the light source.

Sometimes, right at the horizon, a
"mock sun" will appear in vertical contact with the true sun, and occasion­ally attended by a vertical "sun pillar." First noted in Danzig by the German astronomer Hevelius on April 10, 1682, this phenomenon has since been explained as a type of mirage, the mock sun being a reflection of the true sun. The sun pillar is a reflection of light from horizontally oriented ice crystals: on some occasions, it may actually appear both above and below the sun at the same time.

During unusual atmospheric conditions, halo patterns may assume strikingly complex proportions. At distances of 22° and 46° from the sun, individual halos may form, each of which may be colored. In addition, at points on these halos above and below the sun, there may be tangential arcs of light. Passing through the true sun, parallel to the horizon, there may appear a white, luminous band orparhelic circle, along which images of the sun are formed. These are known as parhelia but are commonly referred to as sun dogs, mock suns, or, by seafaring men, as "wind galls."

The most spectacular halo display ever recorded was the Petersberg phenomenon, observed by Johann L. Witt at St. Petersburg on June 21, 1790. This display lasted from 7:30 a.m. the morning until just after noon, at "had everything": multiple halos, tangential arcs, sun dogs, and the color of the rainbow. Another famous spectacle often reproduced in drawings was the one seen by Hevelius at Danzig on February 20, 1661, and known as the Danzig phenomenon.

In the spring of 1912 and the autumn of 1913, brilliant halo systers were seen by many in Great Brita and the United States. In a letter.

Mock sunds in contact with real sun are shown in two stages, and accompanied by sun pillar, in 17th century sketch. Sun pillar, right, sometimes extend above and below real sun, and is lig reflected from horizontal ice crys
"Danzig phenomenon," above, drawn by noted astronomer Hevelius in 1661, is one of best-known recorded displays. Rendition, below, shows the main features of a refraction phenomenon, including 22° and 46° halos, "sun dogs" on both halos, two tangential arcs, and a parhelic circle parallel with horizon.

The British journal *Nature*, an observer wrote descriptively of the sight over Goudhurst on May 17, 191:

"The first thing noted was an object high over the setting sun, just like a moustache brushed into a fierce upward curve. This had a metallic lustre like burnished brass, and marked the contact between two coloured circles, the top one, of which only a one-sixteenth was visible, showing two colors, silvery blue on the concave and rusty buff on the convex. The lower halo was complete down to the horizon, and showed all the colour, while from the sun itself a slender cone rose about halfway up to the moustache, and had exactly the same colour and lustre."

Observations in the United States during early November, 191, extended from the Mississippi Valley to the mid-Atlantic states, with striking displays seen in Missouri, Arkansas, and Virginia. Weather conditions throughout this area were ideal for the displays: a high-pressure system, a thin cover of cirro-stratus, and less wind of any strength aloft.

Halos and associated phenomena apparently occur more frequently than one might guess. The Montsouris Observatory in Paris reported 1,317 sun or moon halos of 22° in a ten-year period, or an average of one ever
three days, while 46° halos occurred about eight times yearly. Sun halos outnumbered moon halos by about three to one. Sun dogs occurred one day in twelve, on the average, and parhelic circles were observed about once every thirty-three days.

Solar halos are most common during the spring in the Northern Hemisphere, with March the most prolific month, and during the late fall in the Southern Hemisphere. Lunar halos, on the other hand, are most often seen in the North during January. Some solar halos have persisted as long as ten hours, but on the average, according to data from the Blue Hill Observatory in Massachusetts, they last about 1.9 hours, while lunar halos last 1.7 hours.

It is understandable that such strange lights in the sky have led people to attribute a prophetic nature to their appearance. One such prophecy frequently has a basis in fact. Clouds that produce coronas often portend precipitation. The adage, "The moon with a circle brings water in his beak," reflects this. A Zuni Indian saying predicts, "When the sun is in his house (corona), it will rain soon." Some of these sayings do not bear close scrutiny, however. "The bigger the ring, the nearer the wet," is actually a misapprehension. A corona will become

"Petersburg phenomenon," above, as seen by Lowitz in 1790, was remarkable for multiple halos and vivid colorings. Drawing, below, demonstrates relations of phenomenon to observer at center. Sun is one hour higher than on page opposite, and some of more spectacular features of display have disappeared.
Sunlight refracting from randomly distributed ice prisms causes halos, but if enough ice crystals are oriented at the same angle, other phenomena appear—the type depending on the amount of light and the predominating types of crystals.

Smaller as rain nears, because the water droplets in the cloud are growing larger at this time and a smaller ring is produced in consequence.

The high cloud cover associated with halos often precedes bad winter weather. A number of studies have been carried out in this field of precipitation prophecy. Data from Columbia, Missouri, gathered early in this century, indicated that precipitation almost always followed a 22° halo in twelve to eighteen hours, and a 46° halo in twenty-four to thirty-six hours. Observations at Blue Hill between 1901 and 1910 indicated that seventy per cent of winter solar halos were followed by precipitation in thirty-one hours.

For more than half a century, the French meteorologist Renou scanned the heavens above his native land, constantly searching for these celestial displays. Yet, so varied are they that Renou, in this long span of time, failed to see one of each kind already recorded. Portentous or merely dramatic, these strange lights in the sky display endless variety. Human beings will continue to watch them—as they did in thirteenth-century England—"... for the wonderful novelty of it."

Sun halo with 22° radius, accompanied by parhelic circle across the sun's face, was photographed by the U.S. Weather Bureau. The term "halo," introduced by Aristotle, is now incorrectly used to describe both halos and coronal rings.
Carved from one solid piece of Water Buffalo Horn, this graceful paddy bird is a stunning example of one of India's oldest handicrafts. Each figure is individually carved and polished by natives of India and is an art handed down from father to son for many generations. Mounted on a rosewood base it stands about 13 inches high and is polished to a glossy black. Here is an example of individualistic styling to be treasured for its simplicity and good taste...Six dollars postpaid.

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North Woods Winter

In snowshoe hare country, the Ice Age seems scarcely ended

By Virginia S. Eifert  Illustrations by Wayne Trimm

The snowshoe hare made enormous leaps up the trail, veered into the shadows of the sheltering firs, and left behind a series of dot-and-dash footprints across the drifts of snow. By the time I had reached the top of the slope and had come into the balsams where the rabbit had vanished, I could not find it, although its whiteness could have concealed it. I felt certain it was watching as I came toward its domain, and was poised to escape if I continued.

This land of the snowshoe hare is a forest of conifers and aspens that lies in the northern United States and southern Canada. In winter, this forest is a place of deep and abiding snow, with a winter that begins in October and lasts until April, and often until May. For at least five months of the year, the ground is white and the drifts grow deeper with each storm and each day of wind.

The land of the snowshoe hare is glacier country. Here, the effect of the last ice sheet is so apparent that it seems to have left but a little while ago. Geologically, it was only yester day when the last glacier melted. Over the terrain of the Middle West the first glaciers of the Pleistocene smoothed everything out, brought Canadian granite rocks to northern Illinois, scattered deep sand and gravel over Wisconsin and Michigan and filled the landscape with boulders, which, one by one, farmers still gather as an annual crop. Ice also deposited a mineral-rich soil over the prairie states, and left low moraine hills where ice, in a bulldozer action...
The snowshoe hare of the North Woods vitally affects the balance of nature in that cold and snow-covered land. Its abundance insures a food supply for the owls, wolves, foxes, and other animals that must survive in the rigorous climate.

moved up debris, and then melted. Under the glaciers themselves, all life perished. This did not happen suddenly, catching everything unaware as in an earthquake or volcanic eruption. The glacier moved so slowly at its advance could not have shown such change from one year to another. Century by century, life continued to exist comfortably just below the great blue-white wall as its uneven edges were forever breaking off and forever draining a little water to the south sunshine.

As the ice covered what once were continent-wide nesting and feeding grounds, mammals and birds simply went a little farther south, or else perished. The great Pleistocene tundra—which had occupied all the land to the Arctic Ocean—was now confined to a more limited area south of the big ice, but this was no special hardship. Mammoths in the marshes had plenty to eat; mastodons fed in the forests; musk oxen grazed on the grasslands; giant ground sloths pulled down tree leaves to eat; six-foot beavers cut poplars and built enormous dams. They dwelt in a green, moist landscape that occupied thousands of square miles below the barrier of ice. Eventually, animals and birds were living much farther south than their ancestors a thousand years before.

The immovable things, the trees and other plants, eventually were overwhelmed and lost, yet even for rooted vegetation there was time for future generations to escape destruction. As the climate cooled, trees tended to produce more seeds on their sunny south sides. Normally dispersing seeds of northern plants sprouted a little farther south, generation by generation, ahead of the ice. Canadian balsams and spruces eventually were growing in southern Illinois and Missouri, arbutus in Kentucky, partridgeberry in Louisiana. The older generations, back in the path of the ice, were finally knocked down and leveled, as the glacier reached them and passed over their fallen forms, but their progeny flourished in the south.

The coming of the ice was made up of advances and retreats; of lobes of ice pushing out in one direction or receding in another, like a chilly amoeba with constantly shifting shape and direction. Four great ice sheets came over the Middle West, each for a different distance and in a different direction. Between, there was a return to greenery and life far up the thawed continent. Yet, over and over, each warming interglacial interval was ended by another advance of the ice.
mass that lurked in the North country.

During the melting times, a braided network of streams, large and small, drained this vast quantity of water down the continent, funneled it into the Wisconsin, the Illinois, the Ohio and the Mississippi rivers. Before the Ice Age, there had been no Great Lakes. Where they lie today—the result of the great, final melting—there were formerly old river valleys, much eroded, then widened, gouged out, and deepened by the action of the glaciers and by their inconceivably great weight. When the ice finally melted, these old valleys were filled with water, which spilled out on all sides to form bodies of water much greater than any there today.

Lake Algonquin then occupied, in the main, the position filled by Lake Michigan now, but it was very much broader. Lake Agassiz extended the present boundary of Lake Superior far into Saskatchewan and Manitoba, and was larger in area than all the other Great Lakes combined.

About 24,000 years ago, ice of the Wisconsin Glacier covered what was soon to become the Great Lakes, but did not extend very far below their southern extremities. Six thousand years later, the ice had gained strength and had pushed determinedly in its final surge south, almost to the Ohio River and the hills of Cincinnati.

Then the ice set about a prodigious melting that lasted for five thousand years, retreating until half of Lake Michigan was open. A thousand years later, when the lake was free of ice, the glacier advanced again.

Meanwhile, a spruce swamp had chance to develop in the shallow lakes and marshes formed by me water in southeastern Wisconsin. When the ice began its final assault, it drowned the spruces. When the ice finally reached the dead trees, it passed ponderous over them, knocking them all flat and pointing in the direction toward which the ice was heading.

Mud and glacial rubble were deposited thickly on top of the felled trees, burying their remains. Traces of this forest were hidden until geologists discovered them near Two Creeks, Wisconsin. Their presence gave the name “Two Creeks Interval” to that last erratic push of i
The landscape, today, is accented by the dark spires of spruce, balsam, and cedar. The broad crowns of the pines stand above all other trees, and the white-on-white of birches, with their black scars and russet twigs, are part of the North Woods picture. Although it is largely a white world, its appearance is varied endlessly with the blueness of shadows on a north slope; by the rainbow sparkle of snowflakes dislodged from pine twigs and cascading through the sunshine; by the winter colors, which range from the purple-brown of the alders to the scarlet of basswood buds, the beige of hazel catkins, and the deep rose of the red pines' bark. In spite of miles of whiteness, it is a colorful land, a land that is full of life.

From the signs all about me, animals and birds appeared to be doing very well. Long since, the weak had perished; late winter contains only the strong and healthy. Everywhere I found their tracks, and most abundant of all in this hilly balsam country were the rabbit highways—lying above frozen bogs and lakes, climbing the hills, dissecting the balsam thickets. So many hares had come along that their chubby tracks had beaten broad lanes through the soft snow. The animals had stood on

and gave it, moreover, an exact date. Carbon 14 dating revealed that those spires were living 11,300 (±300) years ago. This is considerably more recent than anyone had thought that the ice had last come south. The spires at Two Creeks pushed forward the time scale of the Pleistocene's end by thousands of years. Between seven and eight thousand years ago, the ice left the Great Lakes country and has not yet come back.

In the wake of this last glacier, thousands of small lakes were left in lowlands in Wisconsin, Ontario, Minnesota, Michigan, northern Illinois, and Indiana. Wherever ice had lain melting in a depression, a lake or pond formed. Some of these ponds drained quite away, but thousands remained, particularly in the North Woods. The drowned, man-made, curried, wet, lake-strewn sand and gravel of the post-glacial landscape was again ready for the return of living things, ready to become the bed of the snowshoe hare.

Sometimes a hare can reach a speed of thirty miles an hour during short sprints, planting the great hind feet ahead of the forefeet to add momentum.
tiptoe, stood as high as they could reach to peel off the tender bark of young red maples and pines; aspen had been nibbled; even the lavender colored canes of the wild raspberries in the old lumber clearings had been pruned by hares' teeth.

To get about more easily on the snow—and getting about with speed and efficiency can mean the difference between life and death to the hares they find it practical to travel where others have gone before. The land assuring them of a packed-down route that always leads into some thickets tangled hideaway, in case danger pursues. The individualist, taking life hand (and sometimes losing it) may also skip gaily over the frozen lake through forest and over open bog leaving sharp, staccato tracks.

Such tracks appear to be going in the direction opposite that which the rabbit really took. In his hurry the animal puts down his two large hind feet in front of the smaller front feet. By the time the snow is a day and two old, however, the majority of tracks are but indistinguishable in the maze of rabbit lanes crisscrossing the balsam country. The big snow shoe hare that had led me, on my own snowshoes, up the hill to the green dark-green balsams, had followed one of the main routes; the trail led it to the concealment of the tree

Then suddenly, from a few yards away, where it had been sitting such quietude that it had become part of the snow, a big white hare with sooty nose and ear tips burst away and leaped in great bounds across the snow. Startled, careless of following the lanes, it was Alice's White Rabbit recklessly bound for an unknown appointment, rashly printing large, widely spaced tracks for anyone or anything to follow.

The animal went off at a curve and was quickly out of sight. Hares have been known to speed away at thirteen miles an hour, yet they seldom go for very long in a straight line. They may follow a curve, making a large circle, and come back to their haunts again. Counting on this, I waited in the shelter of the firs, while chickadees chittered in cheerful regard for the zero cold.

Raccoon backs down from hollow to nest to forage in snow for anything it can find—from scraps of meat to bus
listening to the chickadees. I could not have thought winter was a simple thing in this land, but I knew better. Many creatures cannot exist in this environment. In a ruthless economy of selection, the animals active in winter are reduced to those able to find food and withstand cold.

Perhaps three-fourths of the birds and in the North Woods in June migrate in winter far to the south—perhaps as far as Mexico, Central and South America. Adult insects largely hibernate, although their eggs, larvae, cocoons, fastened on twig, dead leaf, or bark, still remain, neat capsules of dormancy. Of the mammals, only the migratory are active all winter long. They feed, run and race. The smaller ones are prey for the all-winter hunters—the hungry ones—foxes, wolves, hawks, and weasels. The deer try to find enough greenery and tender leaves on the cedar trees in the dumps to stave off starvation.

All other mammals are adaptable. With a comfortable adjustment to winter, raccoons, chipmunks, rabbits, and beavers find it possible to sleep without requiring much food, sometimes for days at a time. The raccoon dozes on top of a food supply in his den; he seldom needs to leave his bed for a bite to eat. The beavers and coons go down the frozen lake bottom for a lily root or a fish, or an aspen log put there by the gnawing. The fat, deeply furled raccoons, upon awakening early in a hollow tree—the females and immatures together, the males down the trunk and rear across the snow. Anything will do for them—frozen scraps left from the squirrel’s meal, some small creature. In time of real scarcity, birch and alder buds, and even corn, become food.

The porcupines are neither very active nor are they the sort to while away the winter in a den. They get up rather awkwardly in the snow, using a deep, plodding trail worn in the drag-marks of the tail, but they do so in order to get from one tree to another. That day I had come upon a large black porcupine propped in the crotch of a white pine, frost on its quills and a “here I stay” look in the witless, shoe-button eyes. It must have been up there for at least a week, for it had eaten a large gap in the pine twigs and needles and appeared to be contented with both the seat in the crotch and the supply of tender bark and greenery all about. It had only to move to another spot in the same tree to find a fresh dinner.

The large carnivorous animals and birds are the ones that have the grimnest and most urgent winter battle to find enough to eat. In a land as cold and snow-covered as this, it seems impossible that there should be enough to go round. But it is the snowshoe hare, the abundant white rabbit of the North, that provides the answer, the supply that keeps starvation away. In maintaining a balance in the wildlife of the North country, the hare is the single creature affecting it the most. Long ago, the hare often kept Indian villages alive with meat and warm with soft furs in the hardiest of winters; and it fed wolves and foxes, lynxes, and cougars, fed owls and coyotes, martens and wolverines, in the same way it does today.

Yet the hare has a defense, a protection that is perhaps of greater value than would be claws or sharp teeth. Each autumn, white hairs come into the brown coat. The brown falls out and, in about ten weeks, the hare has become pure white. At the same time, if the season is normal, snows have transformed the North into a world of white. Now the hare is a ghost, hidden in full view against the snow. When the winter sun is bright, the hare’s shadow, dark upon the drifts, is more conspicuous than the animal itself. This is a dangerous, telltale image, and the hare appears to avoid its implications by spending its days largely in woods and thickets, in the safety of the shadows.
I looked at my watch. The hare that had departed from the balsams in such a hurry had been gone for eight minutes. If it was going to return in the circular route it was supposed to take, it ought to be back soon. The air was very cold, even in the shelter of the trees. As I was about to give up my vigil, a shadowy ghost came clipping in from behind me.

The hare was so little visible against the whiteness that I had to know it was there before I could assure myself that it had indeed come back. I moved. The hare moved. I could see it plainly now, alert ears tipped with black, a smudge of black around nose and face, eyes dark and alarmed, the rest of the body fluffy and white, almost like an Angora rabbit. I moved my hand, and the rabbit cut out in a big circle again. It would get back again to its thicket, no doubt, but I would be elsewhere.

As I moved away, crunching a trail with my own snowshoes on the drifts, I came upon tracks that a frantic, fleeing snowshoe hare had made. The animal had left the rabbit highways and its tracks were curiously alone and stark in their accurate punching of the broad-spaced signature. But in the deep snow before me lay other tracks, large, purposeful, doglike; leaps that encompassed the trail in magnificent, nine-foot bounds, Wolf tracks.

I felt suddenly alien to these woods. Something else was here, some other presence. I saw nothing, but the tracks were there, and they were fresh, loose snow kicked up around them.

I followed them for a little distance through the openness of the pines until, suddenly, still other tracks lay imprinted. It was the first time I saw snowshoe wanderings here that had come upon any snowshoe trail other than my own and the rabbit. These were different, the round back paw rackets that trappers in the country sometimes wear. The hind paws fell in with the wolf tracks, partially obliterating them.

I was aware then of a furious, biting coldness in the air, a chill that struck inside my inner warmth. I was aware of the wolf and the hunter and the snowshoe hare; let them be. A low gray bank of clouds had risen and now a westering sun had gone under the blanketing. No wonder the air was now so cold. A great silence settled down and the gloom of the clouded skies like a gray cloak upon the forest.

I turned, then, and, still with that sense of being watched, hurried through the deepening cold toward the warmth, the food, and friendliness of my cabin.

By the time I reached the door, the snowflakes were coming down heavily. Their veiling blurred the distant spruces, screened the far aspen dimly at the top of the slope where the aspens began, I could see a ghost shape move into the woods. Through the rushing flakes a raven flapped one wing, feather missing, toward the distant shelter of the snow-clad pines.
The first known attempt to explain the apparent motion of celestial bodies in scientific terms is to be found in Greece, in the fifth century B.C. For several centuries before that time, the Babylonians had accumulated a vast quantity of astronomical observations and had devised some methods whereby they could predict the positions of planets; they left us many tablets outlining their procedure, but we have as yet no record of the theory on which these precepts were based.

The first gropings of Greek philosopher-scientists are poorly known, too, because their original writings were destroyed and gained diffusion only through quotations in historical and scientific works of a later epoch. For that reason, it is not possible to trace the influence of Babylonian thought on early Greek astronomy. In fact, one cannot even say when the first rational cosmology began to take shape. In the fifth century, the disciples of Pythagoras already confronted us with a mature system.

The Pythagoreans held that the earth is a sphere—whereas Thales, a scant hundred years earlier, still believed it to be a disk afloat on the ocean. They also thought that all celestial motions are circular, geocentric, and of constant speed. History does not say by what reasoning they had come to that conclusion, but it may have been nothing more than an expression of their conviction that the sphere and the circle, being perfect shapes, were the only figures worthy of representing the heavens.

Philolaus of Croton, who owed much to the Pythagorean heritage, discarded their view that the earth is the center of the universe, but retained the notion of circular orbits (a notion that would endure until the days of Kepler). He assumed that all the known "errant" bodies—the sun, the moon, Mercury, Venus, Mars, Jupiter, and Saturn—revolved around a central fire. As he explained it, that fire could not be seen from Greece, because that side of earth was always turned away from it, and, furthermore, there was an anti-earth in the direction of the antipodes which forever shielded the earth from the fire's heat.

Unfortunately, the idea of a moving earth was too contrary to common-sense experience to be readily accepted. Philolaus had few followers, and the earth remained firmly static in the theories of the next two thousand years.

In the fourth century B.C., the standard-bearer of Greek cosmology was without a doubt Eudoxus of Cnidus, who has been called the founder of scientific astronomy. Whereas Philolaus' system accounted only in the most general terms for the apparent motions of celestial bodies, the theory of Eudoxus was a complex mathematical attempt to explain these motions in minute detail.

No one could have been better prepared for the task. Born in Cnidus, ca. 408 B.C., Eudoxus studied geometry and medicine, and became a pupil of Plato at the age of twenty-three. After learning Pythagorean astronomy at the newly founded Academy, he traveled to Egypt where he remained for sixteen months. There he found the opportunity to supplement his own observations (at an observatory near Heliopolis) the already extensive me-
al that he secured from Egyptian astronomers. Thus equipped, he was able to draw on the full resources of his theoretical training for the analysis of his observations.

The geometric interpretation of celestial motions devised by Eudoxus is called the *theory of homocentric spheres*. Its avowed purpose was to "preserve the phenomena," that is, to account for all the peculiarities in the apparent paths of celestial bodies, and particularly for the "loops" in the sidereal motion of planets (see diagram).

Eudoxus retained the Pythagorean principles of a static earth and of uniformly circular celestial motions, since, however, the apparent orbits of planets depart appreciably from a circle, he attempted to explain these variations as *combinations* of circular motions. In an ideal case (as left in diagram, above), the combination is accomplished as follows: let the observed body be attached to the equator of a sphere centered on the earth and rotating at a given constant speed. If no other sphere is introduced, the body merely appears to move in a circle around the earth. If however, the extremities of the axis of rotation of its first sphere are attached to a second, larger one, also centered on the earth and rotating at constant speed, the movement of the inner sphere becomes a wobble and the motion of the body is similarly affected. This motion can be modified further by attaching the axis of rotation of the second sphere to a third one, and the same procedure can be continued until the apparent path of the body is fully reconstructed. It need hardly be added that the speeds of rotation and mutual inclinations of the axes must be chosen with care to achieve the purpose.

Since the most complex gyration is that of the innermost sphere, it is easy to understand that the various components of a body's motion are accounted for, in order of increasing complexity, from the outermost sphere inward (at right in diagram.) For each of the five planets (Mercury, Venus, Mars, Jupiter, and Saturn), Eudoxus found it necessary to use four such spheres; the outer one for the diurnal east-west motion; the second for the orbital motion eastward along the zodiac; the third and fourth combined—that is, the two inner ones—for certain changes of latitude and for the loops in the planet's apparent path. Three spheres each sufficed for the sun and moon, since there were no loops to be accounted for, while one sphere served for the stars, which exhibit only the diurnal motion.

Within the accuracy of observation available in his day, Eudoxus' theory gave a satisfactory account of the apparent motion of all the bodies considered, with the possible exception of Mars. This planet's orbit, being somewhat more elliptical than those of Jupiter and Saturn, lent itself less readily to a description in terms of circular motions. Eudoxus' system of homocentric spheres gained wide acceptance. In the ensuing centuries, his original system was modified gradually by the introduction of additional spheres, to keep pace with new data produced by the increasing accuracy of observations. It was adopted by Aristotle without essential alterations and was superseded only by the theories of Hipparchus in the second century B.C.
THE SKY IN FEBRUARY

From the Almanac:

- Last Quarter: February 8, 11:50 A.M., EST
- New Moon: February 15, 3:11 A.M., EST
- First Quarter: February 22, 3:35 A.M., EST

For the visual observer:

Mercury will be most favorable for observation at the beginning of February, reaching its greatest eastern elongation on February 6. Low in the southwest in the evening sky, it will set one and a half hours after the sun on February 1, and one and a half hours after the sun on February 15. The planet will be at inferior conjunction on February 21 (EST) and will remain too close to the sun to be seen in the latter part of that month.

Venus, in Pisces, will be very brilliant (+4.2 magnitude) in the evening sky. Throughout the month it will be high above the southwestern horizon at dusk and will set four hours after sunset on February 1, and three and a half hours after sunset on February 29.

Mars, in Gemini, will fade gradually from +0.5 magnitude on February 1 to +0.3 on February 28, as it continues to recede from the earth. It will be found high in the southeast in the early evening sky and will remain visible most of the night. It will set two hours before sunrise on February 1, three hours before sunrise on February 28.

Jupiter (+1.5 magnitude) and Saturn (+0.8 magnitude) will form a close pair in Sagittarius in the morning sky. They will rise approximately one hour before sunrise on February 1, one and a half hours before on February 15, and two hours before on February 28. At the beginning of the month, Jupiter will be about two degrees west of Saturn. It will pass two tenths of one degree south of Saturn on February 18, and will be one degree east of Saturn at the end of the month. These planets may be distinguished readily by noting that Jupiter is the brighter.

Total solar eclipse:

A total eclipse of the sun will occur on February 15. Although it will not be visible in the Western Hemisphere, it deserves mention in view of the fact that the track of totality, as well as the zone of partial phase, will lie almost entirely over land. This does not happen very often because oceans account for approximately four-fifths of the earth’s surface. Any extended surface area such as that covered by a solar eclipse, therefore, is likely to include a substantial percentage of water.

The path of totality will begin at sunrise in the Atlantic Ocean, off the coast of France. It will then proceed across southern France, northern Italy, the Balkans, and the Crimea, and will then curve in a northeasterly direction across Russia, to end at sunset in northern Siberia.

Partial phases will be seen in all of Europe, in the part of Africa that lies north of the Equator, in the Arabian Peninsula, and in most of Asia. The longest duration of the partial eclipse will be slightly over two hours and forty minutes, north of the Persian Gulf.

The outlook for scientific observations of the total phase is rather poor. European weather leaves much to be desired in February, and the altitude of the sun in the region of totality will not exceed 28 degrees.

On the preceding pages, Mrs. Gossner offers the second in her 1961 series on the growth of cosmological concepts.
WINTER offers unique opportunities for nature photographs, but it brings a number of perplexing problems, too. Since I have had considerable experience taking pictures in the Arctic, people often ask me how I manage to work at such low temperatures. Actually, keeping the photographer in working order is a minor problem compared to keeping the cameras and film working. It is possible to design equipment that will function well in any specified environment but, unfortunately, most of us have to work with cameras, film, and accessories that are designed for normal temperature and humidity. Even in the Temperate zones, it gets cold enough in winter to make most cameras unreliable, if not completely inoperative.

There is a certain amount of lubrication in all cameras, usually a “light” oil. It is light at normal room temperatures, but will act like taffy when the weather gets cold enough. Some imported cameras are loaded with oil at the factory to protect the parts from damp salt air during shipment. When imported by authorized distributors who have repair shops staffed by factory-trained technicians, these cameras are completely cleaned and relubricated before being offered for sale. But every year a number that have not been cleaned find their way to the market. It is always wise to test a new camera thoroughly before using it for serious winter shooting. The better, newer, and more expensive cameras are lubricated sparingly with special aircraft instrument oil, which does not thicken when it gets cold but other problems are not so readily solved.

All camera mechanisms depend to some extent on springs, and springs do not maintain the same tension at all temperatures. Then there is the problem of contraction. The clearances between parts in a complicated camera are rather critical. Metal contracts slightly when cooled, but parts made of different metals will contract at different rates and the spacing between the parts will change. When a weakened spring has to push or pull against increased friction plus sluggish lubrication, it is not surprising that the results are uncertain.

In extremely low temperatures there are even changes in the structure and surface of the metal itself, for which there is no known cure. We can only try to avoid letting cameras get that cold or else we can use specially designed equipment that probably will not be much good for anything else.

Within the more usual range—down to 10°F. below zero or thereabouts there are several steps that will help. The first is “winterizing.” A qualified camera repair man will take the mechanism completely apart, clean it thoroughly, and reassemble it with an absolute minimum of special non-thickening lubricant. He will adjust the clearances and spring tensions to make the parts move as easily as possible. Winterizing, like bathing, is not permanent. It must be repeated at least every fall and often more frequently, depending on the condition of the camera and how much it is used out of doors.

Any camera that is going to be out in the cold for more than a few minutes should be winterized, but that step alone does not insure that it will work. The camera should be tested at the lowest temperature at which it will be used before any picture is taken, and especially before any long trip during which further adjustments may be impossible. A handy way to test a camera is to put it in the refrigerator. Load it beforehand; the roll of film will be a good investment. If it works well after sitting overnight in the food compartment, put it in the freezing section. If you are going to be working in really cold weather, use a picnic ice chest or insulated food bag with dry ice. It takes four to six hours for the camera to get thoroughly chilled and, of course, you will have to make the tests quickly before it warms up. Try the slow shutter speeds and the fast ones. Move all the controls. Take a few frames of an evenly lighted blank wall at different speeds, adjusting the diaphragm for equivalent exposure (for example, 1/10 second at f/1.6, 1/50 at f/7 and 1/250 at f/3.2). By examining the resulting negatives, you can answer two important questions: Is the shutter speed consistent in the different ranges? Is the exposure even throughout the frame? It is also important to wind the film all the way through the camera to check the film transport mechanism.

Some cameras stand cold better than others. In general, the simpler the mechanism, the less there is to freeze up. For this reason, one expert recommends that a press camera be carried on all cold assignments, if only as a “spare” camera. (Of course, the front shutter should be used, not the focal plane shutter.) This is good advice, although the size and weight of camera and accessories might be prohibitive for skiing, snowshoeing, or traveling by dog sled.

Emil Schulthess, whose magnificently illustrated book on Antarctica has just been published, says that he has found focal plane shutters more resistant to cold than focal plane shutters. In this respect, his experience is the opposite of mine (and I do think it is because he was working in the south polar area while I was working the north). Before leaving Switzerland, Schulthess had his cameras completely overhauled at the factory and thoroughly tested in cold chambers. My experience has been that focal plane shutters—of a type commonly used in 35mm. camera develop a lag that causes one half the shutter to travel faster than the other half, with the result that one side of the negative gets too much exposure and the other not enough (see page 63). Focal plane shutters, which open from the center, are more likely to give a uniform exposure, but they tend to slow down, that at a setting of 1/10 second, for example, they may actually give an exposure of 1/2 second. On twin-lens reflex cameras of the “automatic” type, the film-winding mechanism is more likely to freeze than is the shutter. Ti film will wind all right, but it will not stop at the next frame as it should, having not yet tried any of the new single-lens reflex cameras, but I am inclined to doubt that their mirrors or spring-operated diaphragms will work reliably in extreme cold.

Newer cameras are more likely to have cold-resistant lubrication, and some of the newer shutters (ball-bearing type, for example), are good at low temperatures, but old, well-worn cameras sometimes work better because of wear which has increased the clearances between their moving parts.

Unfortunately, the problems of photography in the cold do not end with the camera. Film is also affected. Kod chrome loses 1 1/2 stops in speed at -50° (i.e., the normal film speed of 30 is reduced to 3 1/2). Black and white film suffer a similar loss, and the higher the film speed the greater the loss. For this reason, slow films should be used in winter shooting whenever there is enough light. It is regrettable that tables have been published giving exposure...

David Linton’s byline has appeared under photographs in all the nation’s leading magazines. His camera column is a regular feature on these pages.
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Fun and Adventure in the Woods

Any situation with a lot of light calls for extra care in loading and unloading the camera. If no shade is available, take off your coat, put the camera side, and reach in to the slovenly, insert and remove the film.

The best, and the only reliable, solution to the various problems of snow in the cold is to keep the camera film warm. They need not be as warm as they would be in summer, but just warm enough to insulate that they work readily. The best way to carry a camera inside your coat. I have an old skiers tearing down icy slopes, clouds of snow with cameras slung on their shoulders and whipping in the breeze. They cut a dashing figure, but I doubt that they have many pictures (I have had my Eskimo parka fitted with a zipper so I can carry cameras inside around my neck.) If you travel by air, keep the camera inside with you, not on the trunk. If you use a gadget bag, place it on the floor near the heater. If you travel by air, do not check camera in your baggage; it may be stored in an unheated compartment.

Pocket hand warmers are a convenient source of warmth away from mechanical heat sources. They work only in a confined space, but they depend on the vapor given off by a lighter fluid, and the fluid will not vaporize if it gets too cold. But one or two hand warmers carried inside a gadget bag will keep the cameras and film warm well into the subzero range. Sometimes it is also helpful to carry hot water warmers in shirt pockets and sling a camera around your neck, under your coat.

Whatever source of heat you use, the camera should be taken only when you are ready to shoot, and put away again as soon as possible. Sometimes, of course, this is impossible, as when the camera must be set up long in advance and operated either automatically or remotely. The setups in which animals or birds trip the shutter, or take their own pictures are a case point. I plan to devote a column to traps, but a word about making a trap in the work in cold is appropriate here.

Any arrangement that allows the camera to stand idle and exposed to the cold for a long time invites shutter trouble. In addition, setups using batteries as a source of energy for tripping the shutter or powering speed lights both are prone to battery trouble when the temperature drops. The chemical action by which dry cells manufacture energy becomes sluggish and finally quits. A cold light that recharges in three seconds at room temperature may take a minute or more at 10°F. below zero and probably will not work at all below that. Dry cells (the type of battery used in c
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both indoors and out, and go back forth frequently, resulting to a se- rate set of cameras. On this, Schiltz and I agree. A cold camera suddenly brought into a warm, humid room frightening sight. First, moisture condensed on all the glass and metal faces, clouding the lens like a cat's eye in an eye, and then the moisture free. There is no safe way of removing it from the outside and no way at all of moving it from the parts inside the camera, where the same thing happens, only solution is to wait, sometimes several hours, until the camera was up completely and the moisture evaporates. Even if the camera has been kept relatively warm while outside, the difference may be enough to cause trouble. The best procedure is to use one camera indoors and another outside, leaving the "outside" one where it will not too cold but where it will not be subjected to sudden temperature rises.

No camera on the market can be operated properly by a man wearing regular clothes. This is inconvenient, but not likely to be changed. I wear thin gloves indoors. Even in very cold weather I can take the mittens off long enough to work the camera with gloves on.

From all this it may sound as if the best advice would be to leave the camera at home until spring. Nothing could be further from the truth. Many subjects become exciting in winter, and recording their worth the few precautions it requires. In particular, snow is the photographer's friend. By studying details it plasizes lines and contours; it increases color and brightness and contrast, and makes faces appear weight and old-fashioned. It makes a strong composition out of a scene that would be too "busy" in summer.

And photography probably offers only acceptable excuse for the nature fan who wants to be outdoors in winter. Indoor types are accustomed to think that we who take pictures have a little balmy, and that seriously, and that behavior is normal among us when one wants to do for a braking trip. In a blizzard, it is convenient to be able to say, "Oh, I think I'll just go out and take a few pictures."
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REVIEWS

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SKY REPORTER

NATURE AND THE MICROSCOPE

COVER: This bull's head, with the four-bladed ax between its horns, is actually only an inch across. It is one of some twenty-five Mycenaean gold foil specimens now in the Athens Museum. Until Michael Ventris demonstrated that the little known Mycenaeans were Greek-speaking, the culture that produced such rar art was shrouded in mystery. Ventris' incredibly complex work is described in The Decipherment of Linear B, by John Chadwick (© 1958, by the author here excerpted by Natural History, beginning on p. 8. In April, Chadwick continues the story with a masterful reconstruction of everyday Mycenaean life.

The American Museum is open to the public without charge every day during the year. Your support, through membership and contributions, helps make this possible. The Museum is equally in need of such support for its work in the fields of research, education, and exhibition.
This is an enlargement of just the head from the picture of the flying squirrel we ran in the August-September issue of this magazine. We thought you might like to have a closer look at this delightful creature who is really only the size of a mouse. Since this part was only about one-eighth of the 35mm. film frame, it indicates something of the detail Questar will let you see or photograph at thirty feet.

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Coral Sea

The Great Barrier Reef and Adjacent Isles. by Keith Gillett and Frank McNeill. The Coral Press, Sydney, Australia, $10.00; 194 pp., illus.

One of the greatest constructions of nature, the coral rampart known as the Great Barrier Reef of Australia, ranks among the lesser known areas of the world. From the Coral Sea and Torres Straits to the north and northeast, the reef stretches southward in a long chain of islets, submerged shoals, and banks of coral, losing continuity at about the Bunker Group but continuing, nonetheless, in an enfeebled way to the coast of New South Wales in the latitude of Sydney. Much of its 1,200-mile-long extent has not yet been mapped in detail, although some 350 years have passed since its first discovery and nearly 200 years since the first charts of the reef were prepared by Captain James Cook.

This reef is the product of the industry of untold millions of coral polyps, whose secretions of lime skeletons, one on top of the other, have accumulated into the massive barrier, building steadily upward. These minute polyps, often no more than a few millimeters in diameter, live under rather restricted conditions, requiring clear, warm, marine waters, and bright light. Because of this, the reef-forming corals are not found in temperate waters, nor are they found below about 90 meters even in the Tropics.

Charles Darwin was aware of these restrictions in the habitats of the coral animal and, as a result of his careful observations of many coral reefs, brought forth his famous hypothesis of coral reformation. Although not as widely publicized as his later evolutionary doctrines, Darwin's coral reef theory stirred up nearly as much controversy at the time. The debate still continues, though it has now greatly diminished.

Among the reef types recognized by Darwin was the barrier reef and, in his class, the Great Barrier Reef of Australia specifically. In general, Darwin postulated that if the shallow shelf of continent were to subside slowly, but at such a rate that the upward growth of the corals could keep pace, a rim of coral along the outer edge of the shelf would be formed. An alternative theory proposed many years later, suggests that the solution is not as simple as Darwin postulated, that subsidence is not the only factor, but that changes in sea level also of significance. Adherents of this theory state that the return of sea water from the low levels that occurred during the last ice age is the factor most responsible for control of the upward growth of the reef (Natural History March and April, 1959).

Reviews

A new guide to the Great Barrier Reef

By DONALD F. SQUIRE
Much of Australia's east coast is dominated by a 1,200-mile span of the Great Barrier Reef.

Whatever the cause or control, the corals and their limy skeletons are the building blocks of the reef fauna. Associated with these corals are calcareous algae. Minute plants that nonetheless contribute the bulk of material to the reef; the mollusks, both clams and snails in great profusion; the crabs and lobsters; the brightly colored worms and nudibranchs, and the fish. Together, all these and a host of others constitute the reef fauna, and perhaps nowhere else in the world is there a reef fauna so luxurious, so colorful, so admirably displayed as that of the Great Barrier Reef of the Australian east coast.

Despite the importance of the Barrier Reef as a biologic, physiographic, and economic factor, it has not been biologically exploited as much as one might suspect. With the notable exception of the 1928-29 British Great Barrier Reef Expedition, there have been only isolated research reports dealing with the Reef. Of late, this situation has gradually improved and, with the recent establishment of a much-needed marine biological station on Heron Island, it is more than likely that the quantity of research will continue to increase. Isolation and the vast size of the reef are the factors that have largely contributed to the lack of scientific endeavor. Before the advent of air travel, Australia was remote from much of the scientific world, and her own scientists were engaged in economic and developmental studies. Even for the intrepid, access to the Reef was not always easy. Few islands were inhabited and transportation was irregular at best. Nonetheless, some great work was accomplished.

W. Saville-Kent, of the British Museum (Natural History), conducted a study of the Great Barrier Reef that resulted in the publication in 1893 of a massive tome expounding all phases of the Reef. This remained the standard treatise on the subject until the Great Barrier Reef Expedition of 1928-29. At that time, a group of nineteen scientists, many of whom spent a year at the Low Isles Station, conducted not only ecological and biological surveys but were able to perform basic physiological experiments upon reef organisms, many of which are unprecedented to this day. The scientific reports resulting from the manifold investigations of the group were published in a number of immense volumes, the latest of which did not appear until 1957. Since this expedition, there has been no organized, large scale investigation of the Great Barrier Reef, largely due to a general absence of funds. The Great Barrier Reef Committee, which organized the 1928 expedition, remained in existence and has published a long series of minor reports on the Reef. Only recently has the Committee been able to focus attention again on the Reef and, through the donation of private funds stimulated by a resurgence of local interest, it has been able to open a biological station. This station will provide not only facilities but adequate laboratory opportunities both for students in Australia and for visiting scientists from overseas.

Heron Island, in the Capricorn Group, is one of the few islands away from the shore that is accessible to most persons. Therefore, it is not surprising either that it became a tourist resort or that it is
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second only to the Low Isles in extensiveness of biological investigation. Because of suitability in climate and a location near enough to the outer reef so that the rim of the Reef can be reached under ideal conditions, it has become the site of the new Great Barrier Reef Committee Research Station. Here, in very admirable quarters, which in a short time will be fully equipped, it is hoped that new intensive studies of the Great Barrier Reef will be carried out. Certainly, the ease of transport from Brisbane—the site of the University of Queensland, which has an active Marine Biology program under the direction of Professor W. Stephenson—should both encourage a greater number of Australians to study their unique biological exhibit and foster the visit of a great number of overseas tourists.

Despite its many grandeur, the Reef has not inspired many popular narratives of distinction. One of the earliest, and remains one of the standards, largely because of the magnificent quality of its illustrations. The lavish tome by Saville-Kent, published in 1893, gave the world its first glimpse of the Reef. A series of fifty photographs, taken on slow plates by Saville-Kent himself, showed the region of the northern reef, particularly that of Thursday Island as the Reef was exposed at spring low tides. In a number of other plates, many of the organisms, particularly the fish, were illustrated.

Another important contribution to literature on the Great Barrier Reef came from the pen of the leader of the 1928-29 Great Barrier Reef Expedition, C. M. Yonge. Excellent though it is, his book suffers from the same fault as Saville-Kent's. Although it is the result of an intimate knowledge of a section of the Great Barrier Reef, it was not intended as a general guide to the Reef in the sense of a naturalist's handbook. Other contributions include T. C. Roughley's immensely readable Wonders of the Great Barrier Reef, which for fifteen years was the staple item of the voyager, and more recently The Great Barrier Reef, by William Dakin. The latter is not an outstanding work and is not particularly well illustrated. Arthur Clarke's The Coast of Coral is, of course, an outstanding adventure story.

The absence of a naturalist's handbook for the Great Barrier Reef, its fauna and flora, has been somewhat rectified by the appearance of the work reviewed here, The Great Barrier Reef and Adjacent Isles. McNeill is retiring Curator of Invertebrate Zoology at the Australian Museum in Sydney, and Keith Gillett is one of Australia's leading nature photographers. This book avoids many of the pitfalls of earlier works: it is more convenient than Saville-Kent's in bulk, is more profusely illustrated than any of its predecessors, and is more informative than some. The book will probably spawn many competitors, but at the moment it is most assured. It has 170 photos, 134 in full color.

Following a frontispiece showing the Great Barrier Reef in its early morning blaze of glory, McNeill opens the "comprehensive survey for visitor, naturalist and photographer" with a discussion of the Reef's character, structure, and development. Here one is introduced to the Reef's history (all too briefly presented), its distribution, growth, and composition. In the second of twelve chapters, considerable attention is paid to the Capricorn Group, and Heron Island in particular. Although the detail may seem unwarranted to a stranger (for, after all, Heron Island is but one of the thousands of islands on the Reef), the fact remains that Heron Island is, this time, about the only true coral island that the barrier reef photographer is apt to reach, without great expense and effort. McNeill has been able to capture the charm of the coral islands and for the traveler (naturalist or photographer) who is not so aquatic as the marine fauna of the Reef, there is considerable meat in this chapter (and Chapters 9 and 10, describing Cumber land and Lord Howe Island, respectively) on the terrestrial flora and fauna.

McNeill then turns to the animal kingdom. In successive chapters he considers "Corals and their Allies, outstanding coastal and reef shells, se stars, sea-urchins and their relations, other spectacular members of reef fauna (fish, worms, large crustacea)," and finally, "Crabs and Smaller Crustaceans."

While some invertebrate zoologists may chew the forests fashion in which McNeill has devoted 27 pages to coleterates (including 5 illustrations) and 29 pages to other invertebrates, while giving over only 31 pages to the shells so near and dear to the bookellers—the beach tramper may wish supplementary guide to the shells of the Barrier Reef. Nonetheless, Gillett's book, managed to cram 150 species into his plates without losing balance elsewhere in his book. If the photographic presentation suffers at all, it is in the section on corals; for despite Gillett's abilities as diver, very few color illustrations of the reefs below the tide mark are given. In fact, there are less than a half-dozen photographs in the book that appe are to have been taken underwater. None these equals the quality of earlier effort and certainly are a far cry in comparison to the gaudy showpieces of Clarke's The Coast of Coral; and the angler or spe fisherman seeking to identify his catch will not be pleased with the summary regard the authors have given the members of the Class Pisces.
Among the more interesting chapters is one entitled "Night Descends on a Coral Reef." Normally, the hours of darkness at tourist resorts are given over to activities other than that of prowling about a reef. Although McNell's chapter is not likely to bring about mass reversal of the human activity cycle on the Great Barrier Reef, it will at least suggest to the interested reader that the reef does not rest at night.

Elizabeth Pope, Curator of Invertebrate Zoology at the Australian Museum, has contributed a most comprehensive chapter on Lord Howe Island. This speck of land, about 350 miles northeast of Sydney, New South Wales, is the southernmost coral reef in the world. It is also one of the most spectacular bits of tropical scenery anywhere in the world. Scientifically, much is known about the terrestrial fauna, but next to nothing about the marine. Until recent times, Lord Howe Island was more or less a special preserve of the Australian. A lovely retreat booked solidly year after year. It is hoped that The Great Barrier Reef and Adjacent Isles will put this pot of land back on the map, as it were. It is clear that this description of Lord Howe Island is a labor of love.

The final chapter of the general text—the potential resources of the region—is relatively out of place in a book of this sort. While the fact that little information is given, it seems to have been written to cure insanities. Keith Gillett has contributed a supplementary chapter on marine photography. Although it is undoubtedly authoritative, the level of writing seems to have been pitched a bit high. The rank amateur will find little to sustain him; the professional may well have encountered most of this information, but Americans will be impressed by the number of underwater camera housings seen in Australia, but most are homemade. For the visitor, then, local advice must be sought, preferably before going to the reef areas, for once away from Sydney, prices of most items of photographic equipment, particularly film, increase at astronomical rates.

Appendices concerning protective regulations and practical hints, although a page each in length, will undoubtedly be ignored, with the usual consequences. It is hoped that future editions will have an expanded version hints, furnishing a little more detail in how and where to look for various organisms. Many over-seas visitors will be quite unfamiliar with a reef and will appreciate the hints in more specific detail. A bibliography of identification references would not be misplaced, for many persons will be stimulated to further efforts of the book. The addition of magnification data to these plates on which it is lacking will be an absolute necessity.


This represents the third revision of one of the first comprehensive books on the birds of any of our southern states, which first appeared in 1919. The text of the second edition (1942) has been kept in the present volume almost without change and, where new distributional records have been accumulated since 1942, these are appended as a footnote to each species' account. There are no bibliographic citations to document any of these additions, however. The practice of writing a full account for each species and subspecies has been continued. New accounts have been added for the sixteen forms added to the 1942 list, making a current total of 412 species and subspecies for the state. A map and very brief text on the life zones of the state have been added.

It is regrettable that so little effort has been made to edit or revise the original text. The statement by the earlier authors that only one nest of the Connecticut warbler has ever been found has not been corrected. No effort has been made to discredit the once popular belief that the woodcock carries its young between its thighs. That cowbirds "are social outcasts" and that, "as a rule, other birds do not associate with them" should come as a complete surprise to birddoggers even in North Carolina. Credence is still given to the myth that "a young cowbird will push other young from the nest in which it is hatched."

Some of the plates come from Peterson's Field Guide, while some, but not all, of the rather poor line drawings dating back to the 1919 volume have been omitted. The reproduction of some of the Peterson plates, and especially of the colored plates by Horsfall that appear in my review copy, are the worst that I have ever seen in any book on birds.

In sum, the North Carolina Department of Agriculture would have done better merely to issue an addendum to the earlier editions, perhaps through the medium of the State's own ornithological journal, The Chat. The purported objective, to bring the sections on geographical and seasonal distribution up to date, would thus have been accomplished at considerably less cost. But, of greater importance to ornithology, the misconceptions and erroneous observations embedded within the earlier text would not have been perpetuated and re-emphasized for the younger generation of ornithologists in North Carolina and neighboring states.

Wesley E. Lanyon,
The American Museum

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The Decipherment of Linear B

A once-lost language, in an unknown script, can now be read

By JOHN CHADWICK

The year 776 B.C. witnessed the first Olympic games, a festival, which all the Greeks kept at the precinct of Zeus at Olympia in the northwest of the Peloponnese. Whether it was really the first is doubtful, but it was so reckoned by the later Greeks whose records went back to that date. This is a significant date in Greek history because it marks and symbolizes the adoption in Greece of the Phoenician alphabet, from which ultimately all other alphabets are descended: from the eighth century B.C. onward the Greeks were a literate people, able to record their own history. Thus, Greek history in the strict sense may be said to begin then, and what lies before that date can be termed prehistory. But this was no more the beginning of Greek history than 1776 was of American. Long before the first Olympic games, men and women had lived, fought, and died among the mountains and islands of Greece, and by the only test which can properly be applied—that of language—they were as Greek as their better-known successors in golden Athens and harsh Sparta.

There are three ways of penetrating the fog, which shrouds the early stages of the development of the Greeks; none of them satisfactory or offering more than scraps of information, but by a cautious synthesis allowing some general conclusions. First, there is the memory of people and events that survived into a literate era. The Greeks of the classical period had many legends of a remote past, a heroic age when men were capable of heroic feats and the gods were always at hand to help; many of the heroes were the sons of gods or goddesses. There are no notable events recorded in these legends: the war against Thebes in Boeotia and the expedition against Troy.

The latter is better known, since it provides the background for the twin masterpieces of Greek literature. Traditionally the work of Homer, these long epics seem to have acquired their present form somewhere toward the end of the eighth century B.C.—again that significant century, when writing changed much of the Greek way of life, not least its imagination. Much in the Homeric tale is clearly due to the imagination of the bard. But here at least is a strong pointer to a period of Greek prehistory when the country was organized in strong kingdoms centering round Mycenae—although, in historical times, this was no more than a small country town.

The prospect was enough to persuade a romantically minded German businessman of the nineteenth century, Heinrich Schliemann, to devote his time and wealth to the pursuit of this forgotten age. Thus was forged the second tool of the Greek prehistorian, archeology. With the amateur’s faith and enthusiasm, Schliemann set out, Homer in hand, to bring to light the god-built walls of Troy.

This is not the place to record Schliemann’s career in detail, but we must recall his momentous excavation of 1876, when he found the famous grave circle at Mycenae. For it was the revelation of the wealth and artistry of the civilization he unearthed that convinced scholars of the essential truth behind the legends. “Mycenae, rich in gold...” sang Homer; and the gold came from the shaft graves in quantities to stagger even Schliemann. It took years of patient work by Schliemann’s successors to establish the pattern of events that can now be traced in outline.

Pre-Hellenic archeology, as it has been called until recently, distinguishes three phases of the Bronze Age in Greece: Early Bronze (roughly 2800-1900 B.C.); Middle Bronze (1900-1650 B.C.); and Late Bronze (1650-1100 B.C.). The great flowering of civilization took place first in Crete in the Middle period, culminating in a violent destruction about 1400 B.C. On the mainland, it took place rather later, beginning with the Late Bronze Age and lasting until the twelfth century B.C., when, one after another, all the important centers of Greece were sacked and left in ruins. This last period is called, after the first site to be excavated and its chief center, Mycenae.

Among the many scholars who were in Athens in the 1890’s to see the Schliemann treasures was an English scholar named Arthur Evans. His appreciation of the high level of civilization reached by these Mycenaeans led him to speculate on the economic structure of a kingdom wealthy enough to produce such art and monuments. Evans thought that the Mycenaeans must have been able to write; but no inscriptions had been found in their graves and palaces, and the Greek alphabet—as we have seen—was borrowed from Phoenicia two or three hundred years after Mycenae of the Bronze Age fell.
It was this speculation that spurred Evans to search for traces of prehistoric writing; his attention was attracted by some engraved gems that could be found in the antique dealers' shops in Athens. Some of them had arbitrary collocations of signs, which might represent a kind of script. Evans traced these to Crete, where they were frequently worn by peasant women as charms; the women called them "milk stones." From their study, Evans first identified the earliest script of Greece.

But this was not enough. A few characters engraved on gems were no evidence of the bookkeeping needed to run a civilized country. In 1900, as soon as the liberation of Crete from Turkish rule opened the way, Evans began the excavation of a site already well known as that of Knossos, a classical town of importance and, if Homer can be trusted, the royal seat and capital of a legendary empire. His primary object, the discovery of writing, was rapidly accomplished: the first tablets were found only a week after he had started to dig.

The third method of penetrating the fog of Greek prehistory is even more difficult to follow correctly than the analysis of legend and the often scanty evidence of archaeology. Even today it is all too often overlooked. This is the study of the Greek language. When the earliest alphabetic inscriptions were made, in the eighth century B.C., every little state in Greece had its own dialect. These dialects may be grouped into four main divisions, although these do not correspond in geographical distribution. Quite unlike dialects had a common frontier, while similar ones were widely separated. From these facts, two conclusions may be drawn: first, at one time, all these Hellenic peoples had ancestors who spoke alike, but their unity was broken, and the main divisions developed separately. Second, just before the historical period, each local dialect must have developed out of its own division.

We can apply these facts to the archeological picture with some confidence. It used to be thought that at least three of the four main divisions of dialects had evolved outside Greece and been brought in by successive invasions. This theory has been modified by new research and it now seems more likely that the breakup of the dialects began only after the entry of the Greeks into the Balkan Peninsula. This event has been plausibly equated with the archeological break between the Early and Middle Bronze Age cultures, about 1900 B.C. At most sites there is evidence of destruction at this period, and the new culture shows some features radically different from the old.

The final stage of the movements of the Hellenic peoples is even better defined. The chief areas of Mycenaean power, the sites of the palaces destroyed about the thirteenth to twelfth centuries B.C., were in historical times occupied by one of the major linguistic groups, the Dorians. Starting from northwest Greece (Epirus), these dialects lay in a great arc running down the west coast of the Peloponnese, through Crete, and up to Rhodes and Cos in the Dodecanese. Inside the arc, the Dorians penetrated
Linguistic evidence of Dorian conquest is seen in this plotting of Greek dialects about 400 B.C. The isolated pocket of Arcadian dialect in the Peloponnese matches the related dialect on Cyprus, a known Mycenaean colony. The attempts to decipher a Mycenaean script as Greek. Any solution seriously out of line with Arcadian would have little chance of being a correct one.

There are only three basic ways of committing language to writing, and all known graphic systems use one or a combination of these. The simplest method is to draw a picture to represent a word; these pictograms are then often simplified until they become unrecognizable, but the principle remains that one sign represents one word. This is called "ideographic" writing, and it has been carried to the highest stage of development by the Chinese. For instance, is man, woman; non-pictorial concepts have of course to be expressed by oblique means: thus is big—it may be a picture of the fisherman telling how big the one was that got away! Or, eye (much modified), is equipped with a pair of legs to mean to see. Even in Western languages, we still use ideograms. For example, 5 is not a sign for five, but for the concept of five; it may be read as cinco, cinco, five, funf, and like. The other two writing systems are both made up of elements that, taken together, represent the sound of the word. Thus, a number of signs are needed to write all but the shortest words. The difference between them is that the units of sound represented by the signs may be either whole syllables (pronounceable) or single letters (partly unpronounceable abstractions). A syllabic system splits words up like a child's first reading book: thus "individually" would require five signs. The total number of signs needed is obviously much less than the many thousands that the ideographic system requires. But it may still be high if the language, like English, uses many complicated groups of consonants.

Alphabetic writing, the third system, is generally held to be a Semitic invention (although the Egyptian script pointed the way to it) and it was only fully developed by the Greeks. Its characteristic feature is the small number

All three puzzles are illustrated here: the oldest, or hieroglyphic, script is at left; Linear A, also not yet deciphered, is at center; a sample of Linear B, like the tablets from Knossos, is seen at the right. This specimen was found at Pylos.
of signs needed. Thus, we use twenty-six letters in English (some redundant, like C, K, and Q—all for the same sound in some words), while the more complicated alphabets rarely exceed the thirty-two of modern Russian.

There is an obvious resemblance between an unreadable script and a secret code: similar methods can be employed to break both. But the differences must not be overlooked. The code is deliberately designed to baffle the investigator; the script is only puzzling by accident. The language underlying the coded text is ordinarily known; in the case of a script, there are three separate possibilities. First, the language may be known or partially known, but written in an unknown script. This, for instance, was the case with the decipherment of the Old Persian inscriptions by the German scholar Grotefend in 1802; the cuneiform signs were then quite unknown, but the language, as revealed by recognition of proper names, turned out to be one that was largely intelligible.

Second, the script may be known, but the language unknown. This is the case with Etruscan, which is written in a modified form of the Greek alphabet that presents little difficulty to the understanding of its sounds. But no language has yet been found sufficiently closely related to Etruscan to throw any light on the meaning of the words. Thus, in spite of a large collection of inscriptions, our knowledge of this language is still very elementary and uncertain. Last, we have the combination of an unknown script and an unknown language. In such a case, decipherments have usually been judged to be possible only when they could start from a bilingual text. The Egyptian hieroglyphs began to yield their secret only when the Rosetta stone—with the Egyptian text repeated in Greek—made it possible to equate the royal names in the two versions.

Cryptography has contributed a new weapon to the student of unknown scripts. In theory, any code can be broken, provided sufficient examples of coded texts are available. The detailed procedures are irrelevant, but the basic principle is the analysis and indexing of coded texts so that underlying patterns and regularities can be discovered. If a number of instances can be collected, it may appear that a certain group of signs in the coded text has a particular function; it may, for example, serve as a conjunction. A knowledge of the circumstances in which a message was sent may lead to other identifications, and from these tenuous gains further progress becomes possible, until the meaning of most of the coded words is known. The application of this method to unknown languages is obvious; such methods enable the decipherer to determine the meaning of sign-groups without knowing how to pronounce the signs. Indeed, it is possible to imagine texts in an unknown language that might be read without finding the phonetic value of a single sign.

We must now describe in some detail both the writing that Evans found in Crete and related discoveries elsewhere. Evans was soon able to distinguish three phases, in the history of Minoan writing. In the earliest phase

Non-verbal insights into Mycenaean life, before tablets could be read, are seen here. Above, gem-cut, wounded lion.
dated very roughly to 2000-1650 B.C., the script consisted of pictorial signs, representing generally recognizable objects, such as a head, a hand, a star, an arrow, and so forth. This was the script of the seal stones, but Evans also found a few examples on lumps of clay used as sealings and on clay bars. He named this style “hieroglyphic.”

His next stage dates roughly from 1750 to 1450 B.C., perhaps beginning even earlier. Since the pictorial signs are now reduced to mere outlines, Evans named it Linear A. Examples of this style have been found all over Crete but not outside it (if we except potters' marks found at Melos and Thera). There are a number of inscriptions on stone and bronze objects. The largest single collection of documents, however, is a group of about 150 clay tablets from a Cretan palace, a few miles from Phaistos.

At some date, which cannot yet be precisely determined, Linear A was replaced by a modified form of the script—to which Evans gave the name Linear B. The date of this change would be highly significant; but unfortunately Linear B has so far been found at but one site in Crete. Although the documents using Linear B are firmly dated to the destruction of the palace at Knossos (about 1400 B.C.), it is not clear when Linear A went out of use there.

The relationship between the two systems is perplexing. It is not simply a matter of reducing the early signs to simpler and more easily written forms. In some instances, the Linear B forms are more elaborate than their Linear A counterparts. Now, there is no reason to change the form of a sign in order to write a new language, though it may be necessary to add or subtract, or change the values of, some signs. French has basically the same alphabet as English, though there are certain additional letters (à, è, etc.); k and w are virtually ignored; and some letters have different sounds. The differences between Linear A and Linear B are more like those between the Greek and Roman alphabets (e.g. A=A, B=B, but =G, and =D). Though superficially alike, the differences between the two scripts are clear to a practiced eye. A very obvious difference is that the guide lines, or rules, that separate the lines of writing on Linear B tablets are usually absent in Linear A. A further difference concerns the numerical system. In general, this is very similar, but the treatment of fractional quantities is quite different. Linear A has a system of fractional signs, not yet fully worked out; Linear B has no signs of this type, but records fractional quantities in terms of smaller units (as with tons, hundredweights, and pounds).

Almost all the clay tablets found at Knossos were in Linear B, and the total number of tablets now known—including, of course, many small fragments—is between three and four thousand. All these tablets apparently came from the palace (built in the period called by the archeologists Late Minoan II), which was destroyed by fire at the end of the fifteenth century B.C. It was this heat of destruction that served to bake many of the clay tablets to hardness and so made them durable. For, contrary to the usual

Deer hunt from chariot is another Mycenaean scene cut in a gem in intaglio. Both seals are in the Athens Museum.

Lion hunt on foot, left, is among the most celebrated of Mycenaean antiquities. Scene is inlaid in gold and silver on the blade of a bronze dagger and is shown here somewhat larger than true size. This is also at the Athens Museum.
practice in Anatolia and farther east, the tablets in the Aegean area were never deliberately fired.

Up to 1939, Linear B tablets were known only from this one site in Crete. But a small number of vases had been found in mainland Greece having inscriptions that had been painted on them before they were fired. While these showed some variant forms, they had the same general appearance as Linear B. The presence of a Cretan script on the mainland was not surprising since, on Evans’ theory of a Minoan Empire, Cretan imports might obviously be found at any site under Minoan control. But just before World War II the situation was dramatically reversed.

Schliemann had been led to Mycenae by believing in the truth of the Homeric legend. Could not other Homeric cities be located? This was the question in the mind of Professor Carl Blegen, then of the University of Cincinnati, one of the foremost experts on the prehistoric period in Greece, whose careful work on the site of Troy is justly famous. He set out now to find the palace of another Homeric monarch. Nestor, the garrulous old warrior whose name was a byword for longevity.

Nestor ruled at Pylos; but where was Pylos? Blegen found a likely site some four miles north of the bay of Navarino and, together with the Greek Dr. Kourouniotis, organized a joint American–Greek expedition to dig it in 1939. By an astonishing piece of luck, their first trial trench ran through what is now known as the archive room. Clay tablets were found within twenty-four hours; the first season’s work produced no fewer than 600 of them—similar to the Knossos ones and written in the identical Linear B script. Then war intervened and the excavating could not resume until 1952, when more tablets were found.

To complete the history of the appearance of the texts, we may anticipate a bit to mention the discovery in 1932 by Professor Wace of the first tablets from Mycenae. These were found not in the royal palace, which had been dug by Schliemann and Tsounadas at the end of the last century, but in separate buildings or houses outside the walls of the acropolis, or royal castle. A further find in 1934 brought the number of tablets from this site up to fifty.

Professor Emmett Bennett, who has now become the world expert on the reading of Mycenaean texts, had already established the different systems of weights and measures in Linear A and Linear B. But his outstanding contribution, working on Blegen’s Pylos finds, was the establishment of a signary—the recognition of variant forms and the distinction of separate signs. How difficult such a task is only those who have tried can tell. It is easy enough for us to recognize the same letter in our alphabet as written by half a dozen different people, despite the use of variant forms. But if one does not know what is the possible range of letters, or the sound of the words they spell, it is impossible to be sure if some of the rare ones are separate letters or mere variants.

This is still the position with regard to Linear B. It is to Bennett’s credit that so few such problems now remain
diligent comparison enabled him to set up a table of variants that made it clear—in the case of all but the rarest signs—what was the possible range of variation. At this time the remarkable and gifted young man who is the central figure of our detective story, Michael Ventris, was already exchanging ideas with Bennett. Their correspondence laid the foundation of a friendship, which developed during Bennett’s visits to Europe.

With Bennett’s publication of The Pylos Tablets, in 1951, the scene was set for the decipherment of Linear B. Orderly analysis, begun by Bennett and another American expert in this field, the late Dr. Alice Kober, could now take the place of speculation and guesswork. But it required clear judgment to perceive the right methods, concentration to plod through the laborious analysis, perseverance to carry on despite meager gains, and the spark of genius to grasp the right solution, when, at last, it emerged from the painstaking manipulation of meaningless signs. These admirable qualities were to be provided in full measure by Michael Ventris.

The Linear B texts consist of groups of signs separated by vertical bars; the length of the groups varies from two to eight signs. Accompanying these, in many cases, are other signs that stand alone followed by a numeral; many of these are recognizable pictograms. It is easy to guess that single signs, standing alone, are probably ideographic, that is, representing a whole word. These used in groups are likely to be either syllable or alphabetic. A count of all these signs shows that they number about eighty-nine—the exact total is still disputed. But even this uncertain number is significant: it is far too small for a wholly ideographic system, and it is much too large for an alphabet. Linear B must therefore be syllabic—and a fairly simple form of syllabary, like the Cypriot or the Japanese Hiragana system.

The numerals in Linear B are straightforward; they were tabulated by Evans at an early stage. They are based on the decimal system, but are not positional; there is no notation for zero, and figures up to 9 are represented by repeating the sign the appropriate number of times, much as in Roman numerals. Vertical strokes denote digits, horizontal strokes tens, circles hundreds, circles with rays thousands, and circles with rays and a central bar tens of thousands. Thus 12,345 is written orderby the vertical bars.

The basis of the Mycenaean system of measures, in turn, had been worked out by Bennett in 1950. He showed that the signs, H, I, T, etc., constituted a system of weights, while other goods were recorded in the series T, 4, 8, or 4, 8, 12. As Bennett correctly guessed, the former series was used for dry measure, the latter for liquids. The use of the same symbols for the lower fractions is paralleled by the English use of pint and quart for both dry and liquid measure, the series thereafter diverging to the separate categories of bushel and gallon.

With this knowledge, the signs on the tablets then could be divided into their two classes: ideograms (together with metric signs and numerals) and syllabic signs,
The meaning of some of the ideograms was obvious, but there were many signs too stylized to allow guesswork. It was, however, possible to classify many more of the ideograms with the help of those that could be recognized. Thus, along with horse, A, and pig, P, were regularly found three other ideograms, which were therefore likely to belong to the same category of livestock. It was also noticed that variants of the livestock ideograms occur the commonest being to modify the main vertical stroke or axis of the sign by adding two short crossbars, or divide it into a fork. Evans had correctly guessed that these variations signified male and female animals.

Thus, in many cases, it was possible to deduce the general subject matter of the tablets before a single syllable could be read. Almost without exception, it was clear that they were lists, inventories, or catalogues. For instance, list of single sign groups (word), each followed by an ideogram for man, \( \star \), and the numeral 1, was of course a list of men's names, a muster roll or the like. On the other hand, a word was followed by the word man and number larger than one, and this collocation was repeated on a number of different tablets, the word was likely to be included by a descriptive title or occupational term, like cowherd, tailors, or men of Phaistos.

This method of deduction, since it depends chiefly on studying the same words in different combinations, is often called combinatorial. It leads to valuable conclusions about the meaning or sort of meaning possessed by certain words. At a later stage, these conclusions can act as a check on the correctness of a decipherment, because they are comparatively independent of the syllabic values. For example, if a sign so identified as an occupational term turns out to have been scribed phonetically, to mean cowherds, this lends weight to the phonetic interpretation.

As this is largely the story of Michael Ventris' achievements, it will not be out of place here to give a short account of his life. He was born on July 12, 1922, to a we-to-do English family. He went to school in Switzerland early discovering a remarkable ability to learn languages quickly and by ear. Later, he attended the Architectural Association School in London, flew as a bomber navigator with the R.A.F., and received his architecture diploma in 1948. From an early period in his life, he had been fascinated by the Minoan scripts. This interest he never lost, with rare concentration, he devoted much of his spare time to painstaking studies of the problems they present. Ventris' remarkable mind made him able to discern among the bewildering variety of mysterious signs, patterns and regularities that betray the underlying structure.

**Cryptography** is a science of deduction and control of experiment; hypotheses are formed, tested, and often discarded. But the residue that passes the test grows and grows until finally there comes a point when the experimenter feels solid ground beneath his feet; his hypotheses cohere, and fragments of sense emerge from their camouflage. The code "breaks." In June, 1952, Ventris felt that Linear B had broken. As he transcribed more and more texts, so words began to emerge in greater numbers; new signs could now be identified by recognizing a word which one sign only was a blank, and this value could then be tested elsewhere. The spelling rules received confirmation, and the pattern of the decipherment became clear.

At this moment, Ventris was asked by the B.B.C. to go...
ilk on the Third Programme in connection with the publication of Scripta Minora II, the volume on Linear B that fans had begun before his death and that his friend the critic scholar Sir John Myres had undertaken to compile. Ventris determined to take this opportunity to make discovery public. Thus, at the conclusion of his radio speech, came the astonishing announcement: "During the few weeks, I have come to the conclusion that the ossos and Pylos tablets must, after all, be written in c.c.k.--a difficult and archaic Greek, seeing that it is five hundred years older than Homer and written in a rather prevailed form, but Greek, nevertheless."

Ventris went on to quote four well-known Greek words which he claimed to have found in Linear B: paionios, shepherd; kerameus, potter; khalkos, bronzesmith; khrysoorgos, goldsmith. He ended on a suitably cautious note: "I have suggested there is now a better chance of reading these earliest European inscriptions than ever before, and it is evident a great deal more work to do before great agreement is reached."

And this broadcast made a great impression but I, for one, was an eager listener. The word khrysoorgos, in particular, was encouraging. W did not fit in most forms of Greek of the classical period, but could certainly appear in an archaic dialect, since loss, in Homer, was known to be recent. Eager to try out the theory, I set to work with words from two sets of texts.

Four days, I had convinced myself that Ventris' identifications were in the main sound. I collected a list of forty-three plausible Greek words I had found in the texts (some of which had not then been noted by Ventris) and wrote to Ventris, congratulating him on having solved the solution, and putting forward a number of suggestions. The next thing Ventris did was to draw up a list of words for which plausible Greek equivalents could be suggested. This "Experimental Vocabulary" contained 3 entries (including proper names). A very few of these are now recognized to be wrong and a few more have been edited, but in the main the Greek words he provided were correct, and on which we could build.

Even before Ventris' theory could be published, Professor Blegen--the excavator of Pylos--put into our hands decisive confirmation in full-dress form. One afternoon in May, 1932, Ventris called me from London in a state of excitement--he rarely showed signs of emotion, but at this moment he was a dramatic moment. The cause was a letter from Professor Blegen. He had found some tablets in 1932 which had been examined carefully; they had been cleaned during the summer and only the next spring were they ready for study.

Blegen's letter ran: "Since my return to Greece I have spent much of my time working on the tablets from Pylos, setting them properly ready to be photographed, I have read my experimental syllabary on some of them. Enclosed for your information is a copy of P611, which you may find interesting. It evidently deals with pots, some on three legs, some with four handles, some with three, and others without handles. The first word by your system is to be tiriipoelle and it recurs twice as tiriipoinouliance. The four-handled pot is preceded by quanu, the three-handled by tiriionu or tiriipone, the handless-pot by unu. All this seems too good to be true. coincidence excluded?"
The interpretation of some phrases in this tablet is still disputed, but Blegen's analysis of its contents from the ideograms is evident, and the relative words are clear. Where there are pictures of tripod-caldrons, we have the word τι-ρι-πο (that is τριπός, which means tripod). Then follow the adjectives, which vary with the number of handles. The second term of the compound is always -ος (that is, -οςες, or -οιςες, which means ear). This is the word regularly used in Greek for the handles of a pot; Nestor's cup had four ears. The first part consists of τρι- (as in τριπός), for three; qετρο-, for four; and -oις (the negative prefix), for no handles.

The odds against getting this astonishing agreement purely by accident are astronomical; this was a proof of the undeniable correctness of Ventris' decipherment. All who were unprejudiced could now be convinced that the system worked; further refinements would no doubt be possible, but the basis was obviously sound.

Another equally improbable case of coincidence followed, for which I can claim a small share of credit. In the spring of 1955, Dr. Platon, Director of the Iraklion Museum, told me that he had found in the museum storerooms some trays containing fragments of tablets; they had been exposed to the weather when the museum was damaged during the war, and he thought they would be useless. They were certainly in a poor way; but one large piece was the left-hand end of a two-line tablet; the break showed plainly half a horse's head—the ideographic sign for "horse." Now, horses appear in the Knossos tablets only in the records of the chariot force, which have a quite different form, and in one isolated tablet showing horses and foals—a famous tablet that Evans had published. The left hand edge of that tablet was missing; this seemed to be it. We now had the introductory words for each line, and they read, by Ventris' system: ἰ-γο, horses; and ο-νο, asses. Again Blegen's question could be asked: is coincidence excluded? What are the chances that two series of equine heads will be introduced by words exactly corresponding to the Greek for horses and asses? Such probabilities are beyond calculation; we can only use common sense.

The most exciting prospect now was that of reading all the new Pylōs tablets found in 1952. Ventris invited me to

Key tablet, confirming Ventris' decipherment, is this one found by Blegen at Pylōs in 1952, but not examined until
are the task, and our collaboration enabled us to complete the work in a matter of twelve months or so. *Documents in Mycenaean Greek* was completed in the summer of 1953 and published in the autumn of the next year.

In April, 1956, the French Centre National de Recherche Scientifique, under the direction of Professors d'Hannanne and Lejeune, organized the first International Colloquium on the Mycenaean texts. Nine French and seven foreign scholars from seven countries met for a week near Paris, to discuss the work done and to plan for the future. At this meeting Ventris was, of course, the leading figure; his fluency in French made a great impression, for he was equally at home chatting to the Swiss in Schwyrdutsch, or to the Greek delegate in Greek.

Five months later he was dead—killed in a tragic automobile accident—but the work Ventris did lives, and his name will be remembered so long as the ancient Greek language and civilization are studied.

There still remain a number of the rarer signs in Linear B whose values are not yet established, and the texts that are completely intelligible are few. Yet we may now read, for example: PU-RO ʦje-re-ja do-e-ra e-ne-ka ku-ru-so-jo ʦje-ro-jo women 14 [In translation: At Pylos: slaves of the priestess on account of sacred gold: 14 women.]

But the mere fact of being able to translate the tablet does not automatically answer all questions. Why were these women slaves of the priestess? Which priestess? What was the sacred gold? What was the state of affairs or the transaction that this tablet was meant to record? These are questions that we cannot answer; the facts were known to the writer of the tablet, and he did not expect it to be read by anyone lacking the same knowledge.

This problem is still with us, and will always remain: we cannot know all the facts and events of which the tablets are an only partial record. We have to examine them minutely, compare them with similar documents elsewhere, and check them against the archeological evidence. Imagination may help to fill in the gaps, and I shall attempt to look beyond the bare texts at life in the Mycenaean world; but it is no good pretending we know more than we do.

*To be concluded in April*
Plumes, Threats, and 
White Beauty

The courtship displays of herons are fascinating spectacles

By Andrew J. Meyerriecks

Watching herons can be profitable. It may be undertaken for the simple enjoyment a bird watcher derives from the sight of a graceful egret methodically stalking its prey on a broad marsh, for the photographic record of the activity in a crowded heronry, or for insights into the origin and evolution of complex behavior during courtship that serious biologists may discover while comparing related species.

Some sixty-three species of herons, egrets, and bitterns make up the Family Ardeidae; thus, a variety of forms are available for comparison—a powerful tool for the behaviorist. More species make for more firmly based theorizing. Some species of herons are almost cosmopolitan in their feeding distributions, and a broad range is an asset of studies of the geographical variation of behavior. These may disclose, for example, whether populations of common or great egrets, Casmerodius albus, in Florida Bay, Europe, Africa, and Japan—where Tokutaro Tanaka took the unique photographs on these pages—behave exactly alike. The study of heron sociality is aided by the diversity of social structures found among various species: a few are solitary, some are social only during the nesting season, and many are social in most of their activities. C. albus, for example, tends to be solitary outside the breeding season, but it nests in small to large colonies, often alongside other species of herons and egrets. The question is: how has such social structure evolved?

To many, the word heron evokes the image of a slender, raceful bird, perhaps awaiting its prey while standing motionless at the edge of a stream or pond, or slowly working its way through the shallows. Its dagger-like bill poised for strike. But herons show a fascinating array of feeding methods, ranging from the erratic dashes of the reddish egret to the open-winged whirling of the Louisiana heron. Some, like our own snowy egret or the little egret of the Old World, rake the muddy bottom of their feeding area, forcing their aquatic prey to reveal their hiding places. Others, notably the cattle egret, have left the ancestral water habitat to associate with hoofed mammals and other beasts in order to secure food (Natural History, August-September, 1960). How these diverse methods of feeding behavior have evolved and the role they play in heron ecology are fertile areas for intensive investigation.

The taxonomist is interested in the many color patterns shown by herons and allied species: some, like C. albus, are pure white, others are predominantly dark-colored, and some are heavily striped, blending with the vertical reeds and cattails of their environment. A few are of special interest because they are found in several colors—or phases—regardless of age or sex. A pure white bird, for example, may mate with a dark-colored individual of the
Flailing wings and outstretched neck are part of hostile postures of intermediate egrets, *Egretta intermedia*, in a Japanese heronry. Threats and fights between the birds are common in crowded heronry at start of the nesting period.

But it is during the breeding season that herons delight the eyes of the inveterate heron watcher, offer superb opportunities to the photographer, and give the student of heron behavior his most exciting moments. At this time, herons acquire a distinctive nuptial plumage, show marked changes in the color of their soft parts, and exhibit a host of specialized displays confined to this stage of their annual cycle. No two species of herons have exactly the same kind, number, and placement of their special, breeding season plumes. Long white crown plumes are worn by species such as the black-crowned night heron.
while others display an array of slender, decomposed feathers on their backs—the prized egret plumes of the feather trade. Even the somber American bittern male exhibits white, fan-shaped feather patches during courtship.

Whether bearing a train of superb back plumes or a mere tuft of crest feathers, each species uses its specialized nuptial adornment in a number of displays confined to the courtship period. In species whose breeding biology is known in some detail, the sequence of events is roughly comparable. At first, the male adopts a territory located in a traditional breeding area. Here he proclaims ownership by advertising his presence physically and vocally. During the day, the male patrols his section of the colony, calling loudly and frequently from a number of advertising posts. Often this call differs from the normal notes of the species, although it may resemble an alarm or warning call heard throughout the year. The territory-holding male also attracts attention by virtue of his fully developed plumage, brilliant soft part coloration, and great activity.

The male defends his initial territory vigorously: when a trespasser appears, his first response is usually a low-intensity threat display. This demonstrates one of the two main functions of the specialized plumes. The owner fairly bristles, and his apparent size is increased greatly by the erection of various feather tracts—but mainly of his nuptial plumes. If the intruder does not leave, the owner erects his feathers to an extreme and moves to attack. This normally suffices to make the trespasser retreat but, if not, the owner drives his opponent, male or female, from his display area. If the intruder is a female, however, she will persist, returning repeatedly to a particular male’s domain. Eventually, the male shows a change in his behavior. The female will be allowed to remain on the edge of his territory while he begins to perform a number of displays not previously seen. This is the second major function of the nuptial plumes: they greatly emphasize the movement of different body parts during the male’s performance. There is a neat correlation between the type of plumes, their location, and the part of the body being moved.

Up to this time, the male will have kept the female from entering the nest he has started to build, or at least from the site of the future nest. Furthermore, his displays have been vocal and visual. But soon the male permits the female to approach within touching distance, and now they may engage in mutual contact displays. This is a period of tension, for the male has allowed another heron, even though it is his prospective mate, to enter that part of his territory most vigorously defended—the nest. Tension is relieved, apparently, by mutual feather nibbling and billing. One bird will run its bill through the plumage of the other very cautiously, then its mate will reciprocate. Often the two herons, will face each other and snap their mandi-
Nestlings and eggs are seen in nest in heronry. Nuptial displays of parents may occur even when young are in nest.

bles together rapidly, or even nibble at each other’s bill. Shortly after the pair has formed, such mutual displays are performed on the return of either mate to the nest after a trip to gather nest twigs, or even after a feeding absence. In some species, such mutual behavior may involve an elaborate display of the specialized nuptial plumes as well as billing and nibbling. Indeed, such use of the nuptial plumage may last for the rest of the breeding cycle, although this is not true for all species.

It is clear that the specialized calls, colors, and plumes have evolved to serve a number of functions effecting pair formation and related behavior, for these traits largely disappear during the rest of the year. In fact, as noted, individuals of many species even avoid one another outside the breeding season, and conspicuousness would be a definite disadvantage for them. True, a brilliantly colored male, loudly proclaiming his presence in the breeding colony in order to establish a territory and secure a mate, is vulnerable to predation. But the needs of species continuity and individual safety are balanced in the course of evolution by varying compromises. Vulnerability via prominent advertisement may be offset by social nesting habits, increased aggressiveness, and the like.

We know partial answers to some questions concerning heron biology, but as is so true in science, partial answers often lead to new questions of even greater importance. Of the sixty-three or so known heron species, only fragmentary information on a few species is currently available. The study of herons is highly recommended therefore, to bird watchers, photographers, and biologists alike.

Dr. Meyerriecks, whose works have appeared previously in Natural History, has specialized in heron research and is with the Massachusetts Audubon Society. The unusual photographs on these pages were taken by Mr. Tanaka, an amateur photographer since 1932 and lifelong nature lover.
PAIR OF EGRETS show ruffled feathers on crest and neck during the early stage of nest building, which is also a tense period for male. Relaxation of tension by means of displays leads to synchronization of the pair's activities.
Fox Writers of Sanga

East of the Niger River, answers to questions are read in sand

By CURTIS REIDER

At the rim of the Bandiagara Escarpment in the French Sudan, some ninety miles east of the Niger River port of Mopti, are nine small, mud hut villages, within calling distance of each other, that comprise the community of Sanga.

To one who looks upward from the Séno Plain—which here lies more than five hundred feet below the escarpment's top—the mud villages seem perfectly isolated. Indeed, the one passageway between Sanga and the lower country is a narrow, twisting crevice that breaks the face of a natural, fortress wall. Through this defile, only one person may pass at a time.

The people of Sanga are Dogons. Each village possesses a language of its own. Other languages of intercommunication among inhabitants of these nine villages are the common tongues of Dogon, and Bombari, the lingua franca of this part of Africa.

Essentially, the Dogons are farmers; despite their exotic location, the prosaic onion is their principal commercial crop. Each village maintains its own onion beds, surrounded by woven cane fences to keep out domestic animals. Women tend the onion field from morning until night, carrying on their heads earthenware jugs of water to supply them during their day's work in the blazing sun.

When the crop is harvested, the women pound the onions to a pulp using wooden clubs and singing in cadence as they work. The pulp is then dried in the sun, and carried ninety long miles to Mopti to be traded for dried fish. Fish, together with fowl and goat, constitutes the chief source of protein of the people of the Sudan and the Haute-Volta.

Social stratification in the village of Sanga is strongly defined. Ranking next to the chief in each village is the blacksmith, followed by the carpenters. The children of these social leaders may not marry into the farm families, for this would be beneath their rank in the society.

Blacksmiths, whose craftsmanship is noteworthy, are highly respected both as artisans and as accomplished sorcerers. Using only files and the simplest raw materials, Dogon blacksmiths produce muzzle-loading flint locks that, although not weapons of great accuracy, are true works of art. They also produce farm implements and all metal tools used in the village.

While each village has its own British chief, who resolves such question

Mr. Reider, who has traveled widely through Africa during recent years, is a free-lance writer and photographer.
Draw prints of fox mark designs inscribed in boxes drawn sand by box writer the past evening. Symbols indicate a question to be answered for a villager and craters contain peanuts for fox, whose prints constitute a reply to query.
Mud hut village is one of nine comprising the community of Sanga, set atop the Bandiagara Escarpment, more than five hundred feet above Sénou Plain in French Sudan. The people are Dogons, and the goat is chief domestic animal.

as proper planting and harvesting times, there is also a rigid code of customs that governs life in the villages of Sanga. For example, anyone who causes the death of another person, however accidentally, is punished by permanent exile from the village. He must live outside the Dolo, or cluster of Dogon houses, that is his parent community. His family, by gifts of grain and goats, can regain status, but none of its members may ever speak to the exile again. Such exile, for people as gregarious as the Dogons, is worse than death, and the outcome is often suicide performed by leaping from the escarpment.

Among the most intriguing customs of the Dogons is the curious daily ritual of the "fox writers." Long ago, according to Dogon legend, a wise fox came every night to stand in the center of a circle of village elders and fetish chiefs. The old men would ask questions of the fox, who, being conversant with the Dogon language, would provide them with answers.

The fox knew all things. He knew when to sow and when to reap, which wives a man should pick, how many sons they would bear him, and how many goats a father should request for the hand of his daughter.

One fateful night, after many months of famine, a hunger-crazed villager killed the wise fox and ate him. However, the fox’s spirit survived, so the legend says, although the ghost fox would never again speak to the old men of the village. But in return for food, the ghost will still give silent answers to their questions.

Each evening, one or two old men leave their respective villages and pair to a large tree near the site of the present Christian mission building in Sanga. The fox writers, who
task is hereditary, smooth out the sand beneath the tree. Then they place sticks, stones, and peanuts in various ways within marked squares, each arrangement of objects representing a question that has been posed by a townsman. During the night, the ghost fox comes to eat the peanuts, thus leaving tracks and disturbing the arrangement of the sticks and "writing." At dawn, the old men return to read in the sand the messages that answer the villagers' questions (see photograph, page 26). The fox writers live on food and money offered in payment for the answers thus obtained.
“Caves of the Ancestors” in the Bandiagara Escarpment have interior structures of mud, which were formerly used as granaries, but which are now ossuaries containing bones of an estimated thousand tribesmen. They were slaughtered
Monsters are during a night raid by an entire tribe of Fula warlike, formerly Songhay enemies of the Dogons. Fula men under the leadership of their fierce warriors attacked the Dogon territory, led by their king, protecting the Dogon villages from near the Sanaga river.
TREASURES FROM THE EARTH
FOR THE COLLECTOR AND DECORATOR

Thunder eggs are partially or completely filled openings in rhyolite nodules. These polished halves are handsome pieces showing the perfection of nature’s handiwork. The name is derived from old Indian legends. The Indians believed they were formed by their gods hurling thunderbolts from the sky. The small solid thunder eggs are from Oregon. The larger ones have quartz lined cavities and are from Mexico.

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This is the 110th of *Nature Magazine*’s special educational inserts
THE MARINE ALGAE

In sea’s “weeds” may lie the future’s insurance against starvation

By E. Laurence Palmer

Quintus Horatius Flaccus, more familiarly known to us as Horace, once wrote that: “Noble descent and worth, unless united with wealth, are esteemed no more than seaweed.” While the time span back to the day of Horace—who was sixty-five years old at the beginning of the Christian Era—is of course relatively short, geologically or biologically speaking, and the facts and principles on which science is based have not changed, our knowledge of the marine algae has been enormously expanded. Today, we see in the marine algae—Horace’s “seaweed”—a potential for great wealth and a great opportunity for new discovery.

Few references to the seaweeds appear in either Testament of the Bible. The usually all-observant Shakespeare seems to have given them but little attention. Even Hemingway, considered by some as the spokesman for our time, writes more about the great fishes than of the plants that form the basis of their food supply.

It is probable that life found early expression on earth in the seaweeds, and it is possible that these same “weeds” may offer us a major hope for survival in some future time. They may perhaps guarantee the human race a future that will not be characterized by near starvation conditions. The sea and its weeds, having generously nurtured us in the past, may well be utilized to save us in the future.

The thirty-eighth unit in this series of education inserts was published in February, 1946; like this unit it dealt with various species of marine algae. There no duplication of the species considered in the two units, however. Among the thirty-two species dealt with, no extensive notice was given the highly significant plankton organisms, some of which should be thought of as marine algae. Nor did we consider the relative few—but sometimes significant—flowering plants that are to be found in the sea and associated with marine algae in brackish waters. The plants we consider here are those that live in salt or brackish water, and that are, have been, attached to bottoms where the water is deep enough to cut off light needed for plant growth.

For the most part, the world of marine algae is limited to coast lines. However, coast line plants are often torn free from their original attachments to the bottom and continue to grow and develop while they drift.
the ocean. Under these circumstances, it is possible to find marine algae anywhere near the surface of the sea, from the Arctic to tropical regions; and on rocks, sand, or in the ocean depths.

Among the factors that determine the kinds of seaweeds to be found in a particular place are sunlight, temperature, the chemical and physical nature of the sea bottom, violence of wave action, pollution, abundance of animals that feed on the plants, and a number of other factors. Only about two per cent of that part of the surface of the earth covered by the seas possesses water shallow enough to permit the entrance of light sufficient to support plants; and much of this area has a bottom of loose, shifting sand or mud, or is otherwise unsuitable for plant growth.

There is justification for the division of the seaweed-supporting areas of the oceans into a number of subareas. For example, there is the area permanently below the low tide mark, an area that never becomes dry, and is never subjected to the extremes of heat, light, and violence that affect the strip between the lines of lowest and highest tides. This is an area that may be explored with varying degrees of safety, and for varying lengths of time. In the intertidal area, most of the plants and animals are first submerged in sea water for about six hours and then exposed to drying for a similar length of time, twice a day. The existence of life under such conditions presupposes an ability to make some remarkable adjustments, or adaptations. The reproductive, feeding, and protective activities of living organisms must be fitted into the situation, and no two kinds of living things meet these conditions in an identical manner.

It does not take a trained ecologist to recognize the fact that there are several different zones of plants along our shore lines. There is an uppermost beach area, above the highest tide, that is sprayed by spume and reached occasionally by the highest waves. Marine algae that require submersion in salt water need not, of course, be expected here, at least not in abundance. This supralittoral zone is wet by the high spring tides and by storm waves; and from this zone, down through the tidal zone, we may recognize several other areas on such places as exposed rocks, piers, or pilings.

The highest tide area is ordinarily bare of most marine algae, but it sometimes displays Enteromorpha and Cladophora, described in the chart section that accompanies this insert. Below this, down to the low-water mark, is the realm of the rockweeds, which are more fully described in the thirty-eighth insert. Below the area marked by the highest low tide and lowest high tide, is the region dominated by, or at least characterized by, plants of the order Laminariales. (Refer to numbers 6-11 in the tabular description, and to other plants of the order shown in the thirty-eighth insert.) Also found in this zone are the coral-like algae.

The plants of this general area must be able to survive conditions that would be fatal to most plants. They must withstand the heating of waves that strike them...
from all directions. They must survive extremes of heat, light, and desiccation, and they must support the inroads of the animals and plants that may feed upon them. Some must survive burial by shifting sands, and if grinding of loose material on the ocean bottom. Not few must exist in the pollutants that float on the surface of the ocean, and that may become especially concentrated along the edge of the shore.

Botanists are not wholly in agreement as to the proper classification of marine algae, and since these students of plants do not agree, we cannot criticize inconsistency of students who propose other arrangements.

**Basically**, the marine algae belong to four or fi groups. The blue-green algae—the Cyanophyceae or Myxophyceae of some authors—may be either fixed or free-floating, and may be found abundantly in fresh as well as in salt water. Some of these were considered the sixty-ninth insert of this series.

The green algae belonging to the Class Chlorophyceae include link confetti, the "green ball" shown in this inset as sea lettuce as shown in the thirty-eighth insert, and mc of the algae that are figured and described in the sixth insert. They are for the most part green in color as their class name implies, and may be either free-floating or fixed to the sea bottom or rocks.

The brown algae belonging to the Class Phaeophyceae include the oyster thief, stick bag, devil's shoelace, sea sucker kelp, sea cabbage, sea palm, pompon, feather boa, and the woody chain bladder algae, all figured in the insert. Eight of the algae considered in the thirty-eighth insert also belong to this group. Few of these are found in fresh water. They are considered by some as the most advanced of the thallophytes; they reach the maximum development in the cooler seas, and possess the ability to dominate the rocky intertidal areas. A giant kelp of the Pacific, growing off the Chilean coast in waters to about 250 feet deep, belongs here. At least one of the brown algae grows on other plants.

In this insert we have specifically considered a number of the red algae belonging to the Class Rhodophyceae. Nine of the group were considered in the thirty-eighth insert. Six are in this unit, and one was in the sixty-ninth unit. Most of the members of this group are marine, as are perhaps the most beautiful of all the larger marine organisms. The common name may be a misnomer, because we find members of the class that are red, purple, brown, violet, and green, and some that may be iridescent.

On the whole, these plants are found at relatively shallow depths, and while some of them may attain a length of more than six feet, most of them are much smaller than the brown algae. The red algae are most abundant in temperate seas, and relatively few are abundant in the intertidal zones. Some have played a prominent part in the building of lime deposits, and may be closely associated with the corals.

Certain writers recognize a special group of algae known as the yellow-green algae, prominent among which may be the diatoms, considered by some as belonging to the Class Bacillariophyceae. Some of these are free-swimming and motile. Some merely float; others may be attached by strings of mucus. They serve as food and shelter for many aquatic organisms, and may be t
basic food for minute organisms that in turn feed larger creatures. They are found in fresh as well as in salty and brackish waters, and from their shells man makes polishing powders, explosives, toothpaste, filters, and cement strengtheners. Their reproductive capacity is tremendously large, which may, in the long run, affect man.

We have all, at one time or another, calculated the age of a tree by counting the rings of its wood. To a limited extent, we may do something of this sort with certain of the marine algae. Some of these algae are short-lived, many of them being annual; while some may live for a number of years. The pompon shown in the accompanying chart section sheds some of its streamers each year, leaving a series of scars that allow one to recognize the growth of the year.

Normally, a submerged habitat may be considered more favorable to the growth of marine algae than an area exposed to the air, to large temperature variations, or to other extremes. Interestingly, the prolific growth of deeply submerged seaweeds reduces the amount of sunlight that can penetrate the water, and therefore a heavy growth may affect a given area botanically.

Some marine algae may grow in length at the rate of ten inches a day, but such a rate is not common to all algae, nor does it remain constant for any given alga. A plant that may grow at the rate of ten inches a day from March to June may grow at the rate of only one inch a day during June and July. Then, too, the growth of plants in deep water may be more rapid than that of plants in the shallows. Competition is often a major factor affecting rate of growth and an early seasonal start may be of importance. Sediments in the water may at times cut down the available light at various depths, and affect the growth of algae there. In addition, seasonal storms and floods may sometimes considerably affect the prosperity of a loosely fixed or free-floating seaweed.

Most of the marine algae possess two or three methods of reproduction—some have more. The simplest mode of reproduction is by fragmentation, in which each of the fragments becomes an independent organism. Then there is reproduction through the development of asexual spores, some of which swim and some of which do not. Sometimes these spores are produced in specialized regions of the plant, and in special structures; but this is not necessarily always the case.

In some algae similar spores may unite, the combined spores forming a new plant. In other algae, spores that differ conspicuously may be formed. A pair of unlike spores may unite in true sexual reproduction, and from such a union there may develop a new, individual plant. When this is the case in the marine algae, it is common for the resulting plant to produce asexual spores, so that there is an alternation of generations between plants that produce sexual spores and those that produce asexual spores. This alternation of generations in the marine algae is infinitely varied—to the delight as well as the occasional consternation of the botanist. Seasonal influences may affect the nature of such generations rather profoundly, but over the course of time a species continues to exist in spite of its several variations.

The origin of the marine algae is lost in geological antiquity. We can reasonably assume that, where the normal products of algal activity are found, algae must
have existed to produce them. (There are, however, coral and lime deposits and diatomaceous oozes in geological deposits that do not yield samples of the organisms that must have been their creators.) The earth's oldest fossil remains may well be associated with marine algae; and it is safe to say that the marine algae will be among the last representatives of life on earth.

Botanists who pry deeply into the behavior of marine algae—and fresh-water algae as well—recognize that their growth may be affected by various physical factors. This is also true of their reproductive processes. There have been some most ingenious studies based on the exposure of marine algae to light, pressure, movement, electricity, various chemicals, and to combinations of these factors. As a result, some of our laboratory manuals can now specify the proper agent for desired experimental results in dealing with the algae. Also, biological supply houses are now often able to submit materials that make it possible for a student living inland to learn as much about the algae as those whose homes are on or near one of the seaboards.

A kelp-covered rock at the tide line is almost always worthy of study. When the tide is out and the sun is high, environmental factors are most hostile for the marine algae. Water supply is limited. Temperatures are excessive. Light may be intense. Kelp-eating animals roam the shores, feeding on the plants. Portions of the plant may wither and die, or become severely fractured. Fortunately, however, the volume of the kelp blanket is such that, while exposed parts of a plant may suffer, there is much plant material that is protected through being covered by a soaking blanket of the kelp itself.

Plants near the low-tide mark may be subject to severe treatment for only a few minutes, until the tide turns; and even those higher up may be washed now and then by the dashing of the waves. It is interesting to note that the intertidal strip is more heavily populated with sea plants that may survive emergence than it is with land plants that can survive submergence. An evaluation of the comparative hardiness of land and marine plant can be made, based on the evidence of an intertidal strip and might well prove most rewarding.

The destruction of marine plants by desiccation, predation, and by violence and crowding is obvious an important; but what really counts is whether such destruction is greater than the constructive work done by the organisms over the same period of time. The fact that there is a great surplus of observable material shows that the constructive forces constantly win. If such an observation is extended over the course of a year, it will be evident that there are periods when "hard times" are the order of the day; but in the long run these are balanced by the periods of prosperity.

It may be well to think of this conflict not only in terms of what happens to a given plant, but of what happens to the biological material collectively. The crowding of healthy material may not only save portion of a plant, but it may also protect smaller or more immature individuals of the same kind of plant, or perhaps less hardy plants of other species.

There are pessimists who say that human starvation is inevitable in the distant future. Optimists, however, point with considerable confidence to the great potential of the marine algae. Such plants may be food for man, for domesticated beasts, and for animals in the wild. They have an important place in man's vision of the future. Even today the marine algae form the basic diet of many human beings, and seaweed often enters obtrusively into our diets here in America. The role of some marine algae as food for human beings are mentioned in the chart section of this insert.

Health, of course, is a topic important to all of us, an
Most studies of disease involve the study of microscopic disease organisms. We can all identify a flock of geese without studying the details of its individuals; and so it is that microbiologists have learned how to recognize a colony of microorganisms without troubling to observe its individuals. This sort of study frequently involves the culture of the organisms on some medium that possesses a variety of special qualities. Agar is such a medium in common use, and agar is basically a marine alga. Its production is essential to our present-day civilization. Within the past few years, the Russians have announced that they are producing a superior agar from marine algae not previously used for the purpose. They have not yet claimed to have created algae, but they have unquestionably found new uses for the plants that for hundreds of years were "esteemed no more than seaweed."

Much of the gelatin used in cookery may originate in the marine algae, and many of the foods used by hikers and explorers make use of marine algal material, which is easy to dry and yet which, with the addition of water, is quickly restored to the desired volume.

It is pleasant to assume that the supply of marine algae is inexhaustible. Americans have made that same assumption in the case of their forests, their topsoils, their buffalo herds, and their passenger pigeons. Methods we are now developing for harvesting marine fishes presupposes an inexhaustible supply of marine algae on which such fishes are dependent, so we shall probably have to learn our conservation lessons once again.

Today there is much concern over the needless destruction of marine life, and it is most encouraging that our colleges and universities are recognizing the importance of marine problems. Even those institutions located far from the ocean shores are providing specialized training that may make our future dealings with the sea much more intelligent than they have been in the past.
<table>
<thead>
<tr>
<th>LINK CONFETTI</th>
<th>DESCRIPTION</th>
<th>RANGE AND HABITAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Enteromorpha intestinalis</td>
<td>Slender, flattened ribbons to one cell thick, to more than one yard long, tubular, bright green, to 1/2 inch wide, usually gas-filled, and with constrictions that give plant intestinal appearance. This species is unbranched, and threads are usually less than 1/10-inch wide. Highly variable.</td>
<td>Almost world-wide distribution, with most species restricted to salt water. Habitat ranges from polluted through brackish to pure sea water, with specimens on ship bottoms able to survive fresh water temporarily. Attached by basal area to bottom between 3-foot and mean low tide marks.</td>
</tr>
<tr>
<td>Chlorophyceae, Ulvichiales, Ulvaceae</td>
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<tr>
<td>GREEN BALL</td>
<td>A bright green ball about the size of a small lemon, which, if detached, may spread into a thin, green tissue to 3 inches or more across. The jelly balls include branched or unbranched threads of barrel-shaped cells, attached end to end.</td>
<td>More than a dozen Pacific coast species, and many on the Atlantic Coast. May or may not be conspicuous in tidal pools, with “ball” effect most common where wave action on sand is present. The plant may hold sand particles at branches when it is growing on rocks away from free sand.</td>
</tr>
<tr>
<td>Cladophora trichotoma</td>
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<tr>
<td>Chlorophyceae, Cladophorales, Cladophoraceae</td>
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<tr>
<td>SEA STACHORN</td>
<td>Erect, spongy, forked, cylindrical, with branches equal but not straight. Plants arise from branched filaments that are without cross-walls. Commonest species have erect, unbranched stems, commonly inflated, while others do not. Shoots are to 10 inches long and to 1/4-inch wide.</td>
<td>Commonest Atlantic species may be dichotomous, while commonest Pacific species may be fragile. This species may be greenish black or coated with white hairs near low tide level from length about 10 times the diameter, or more. Most abundant in warmer seas.</td>
</tr>
<tr>
<td>Codium fragile</td>
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<tr>
<td>Chlorophyceae, Siphonales, Codiciaceae</td>
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<tr>
<td>OYSTER THIEF</td>
<td>Like an olive-brown, inflated balloon to 2 inches through when young, appearing as a floating globular sac filled with water or air. In flower age, however, these bubbles burst, and the deflated unit may bear wrinkles resembling the surface of the brain. Surface may bear tufts of hairs. Crisp, not slippery.</td>
<td>On Pacific coast, found from Alaska to southern California, from the shallows to 40 or more feet in depth. May be found growing on rocks, as well as along the length of our western coast, but with some seasonal variation obvious. Believed introduced to U. S. from Europe; is world-wide in warm areas.</td>
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<tr>
<td>Colpomenia sinuosa</td>
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<tr>
<td>Phyophyceae, Punctariales, Encoeliaceae</td>
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<tr>
<td>STICK BAG</td>
<td>Appears like a bag attached to an alga. May be to 1 yard long and to 4 inches through, but is normally much smaller; is attached by special structures through a solid base, and is commonly olive-tan to brown in color. It is commonly borne at right angles to the supporting host alga.</td>
<td>Commonly grows as attachment to woody chain bladder alga (which see) from Alaska to southern California, and from near surface to a depth of more than 30 feet. Not commonly abundant or conspicuous, and may seem absent in particular seasons. May seem bladelike at times.</td>
</tr>
<tr>
<td>Codiolodesme californica</td>
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<tr>
<td>Phaeophyceae, Punctariales, Encoeliaceae</td>
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<tr>
<td>DEVIL'S SHOELACE</td>
<td>Slender, ropelike fronds less than 1 inch in diameter, frequently to 12 feet long and reportedly to 40 feet long. Colorless hairs of a delicate nature cover young plants, but old ones commonly have decayed tips. Whole mass looks like an aggregation of snakes. Brown, with a central air cavity.</td>
<td>This species is well represented on each side of the North Atlantic, is common in low tide level from New Jersey north, and is usually attached to inorganic material. The related C. tomentosum ranges north of Cape Cod. C. Ilum ranges from New Jersey to Baffin Bay.</td>
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<tr>
<td>Chorda flum</td>
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<tr>
<td>Phaeophyceae, Laminariales, Laminariaceae</td>
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<tr>
<td>SEERSUCKER KELP</td>
<td>Length of flat blade may be to 10 feet and width to 1 foot, arising from a tough, branched holdfast, and displaying up to 5 prominent longitudinal ribs, with 3 showing on one side and 2 on the other side of the blade. Area between the ribs is shivered or puckered, giving the name &quot;seersucker.&quot;</td>
<td>Four species and one variety of Costaria are now recognized along coasts of Pacific Ocean in Japan and North America, ranging from Bering Sea to western California, and found in deeper waters in southern part of range. Some authorities consider that there is but one variable species.</td>
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<tr>
<td>Costaria costata</td>
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<tr>
<td>Phaeophyceae, Laminariales, Laminariaceae</td>
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<tr>
<td>SEA CABBAGE</td>
<td>Compact mass of fronds, densely crowded into something that resembles a cabbage head with individual &quot;leaves&quot; almost circular, and from 15 to 18 inches across. Mature plants are fastened to rocks by holdfasts, or fibers that develop from blades' bases. Blades are either smooth or wrinkled.</td>
<td>Two species of the genus cover our Pacific coast from central California to Bering Sea, on rocks near low-water mark where wave action may be most violent. H. sessile may be found south to central California. Its blades are dark brownish green, with a heavy leather-like texture.</td>
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<tr>
<td>Hedophyllum sessile</td>
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<tr>
<td>Phaeophyceae, Laminariales, Laminariaceae</td>
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<tr>
<td>SEA PALM</td>
<td>May be found in &quot;groves&quot; where the surf is the most severe, with submerged individuals superficially resembling palm trees, usually with many arising from a common base. &quot;Stems&quot; up to 2 feet tall, with upper portion flattened, and with a hundred or more 12 x 2-inch streamers.</td>
<td>From Vancouver Island, in British Columbia, south to central San Luis Obispo County in California. Blades have sharply toothed margins and deep longitudinal grooves alternating on the two sides. Some may be found in partially submerged rocky ledges somewhat offshore.</td>
</tr>
<tr>
<td>Postelsia palmaformis</td>
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<tr>
<td>Phaeophyceae, Laminariales, Lessoniaceae</td>
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</tbody>
</table>
ECOLOGY

Basal or other tissue may break to form floating pieces that may vegeta-
tively, or may yield 4-8-16 zoo-
spores, each with 4 mobile swimmers; or may yield sexual cells, each with 2
swimmers, which may have sexual un-
ion. May develop without union par-
thenogenetically, or be a resting stage.

Plants may be solitary or grow in
crowded clusters attached at base, or
sometimes free-floating. Most com-
monly observed in tidal pools or just
below low tide mark in protected
areas, and observable at almost any
time of year as a green mat of threads,
usually attached to the bottom.

Vegetative tissue may divide to pro-
duce new individuals, or cells may
yield identical, oval, 4-swimmered
cells freed from terminal branches
through upper pore; or may yield 2-
wimmered gametes, which may unite
sexually or germinate without union parthenogenetically.

Asexual spores are not pro-
duced. Cells yielding sex elements are
done laterally, with the male yellow-
ish green and the female blackish
green. United gametes form a zygote
that develops into a new plant body.

Green ball is perennial and may hold
ball shape in aquarium for more than
eight years. Expanded cushion forms
may occur in deeper water where
there is but little water motion. Some
species of Chalodaphne are limited to
fresh water, while others are marine
or cosmopolitan in many respects.

Plants may divide to reproduce vege-
tatively. Asexual spores are not pro-
duced. Cells yielding sex elements are
done laterally, with the male yellow-
ish green and the female blackish

green. United gametes form a zygote
that develops into a new plant body.

REPRODUCTION

Vascular tissue may divide to pro-
duce new individuals, or cells may
yield identical, oval, 4-swimmered
cells freed from terminal branches
through upper pore; or may yield 2-
wimmered gametes, which may unite
sexually or germinate without union parthenogenetically.

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duced. Cells yielding sex elements are
done laterally, with the male yellow-
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green. United gametes form a zygote
that develops into a new plant body.

Unicellular spore cases are unknown
but many-celled reproductive organs
are found around hair tufts; these
opening in autumn free units that act
as zoospores, those in spring be-
having like sexual anitds. Not always
agreed whether main tissue represents
a gametophyte or a sporophyte stage.

Spore cases are only one-celled, usu-
ally separated from each other, pear-
shaped, and imbedded just below tis-
sue surface. Gametophytes are micro-
scopic threads several cells high,
which produce gametes that resemble
each other but which unite sexually
to produce basis for the sporophyte.

An annual plant that appears during
May, and which may disappear by
August. It may be abundant where
host is present on which it may grow
but apparently utilizes host only for
support and is not a definitely destruc-
tive parasite to be kept under control.

While many marine algae favor the
warmer waters, this species does well
where it is cooler; sometimes dense
growth of this species rival in beauty
the better-known biological forms. The
North Sea and the English Channel
are reported to have beds to 20
miles long and to 600 feet wide.

These dark-brown plants may grow
rapidly, a blade increasing as much as
1 inch by day and half inch by night,
with growth mostly at the widest part
of the blade near the base. In 9
weeks, the hull of a sunken ship had
become completely covered with this
particular kelp.

Found in crowded masses on rocks
heavily beaten by the waves, they
provide welcome food and shelter for
weaker fishes and for the small ani-
mals that play a part in the economy
of the site. The presence of mucilage
ducts on the blades may contribute to
survival under existing conditions.

The glossy olive-brown stipe that sup-
ports the fronds is clastic, and it may
be bentdifficulty to recover when pres-
sure is released. It is doubtful if any
other plant can more genuinely ex-
press the condition and turmoil that ex-
sists in a wave-beaten, rocky shore of
caves and crevices.

Useful as a basic food for fishes and
other marine animals, and may serve
as a purifier—or contaminant—of wa-
ter. Deflated threads may have re-
leased green cells or zoospores, leav-
ing the threads colorless. Species
recognition requires ability of the spe-
cialist in many cases.

Basically identified with pollution and
purification of water and with service
as a basic food for fishes—or of the
animals on which fishes feed. May
serve in some capacity as silf or sand
anchor, assisting in stabilizing loose
material on the bottom of waterways
—fresh, salt, or brackish.

Closely related forms may be impor-
tant in the development of algal reefs.
The Hawaiian food limu may include
Codium, with some forms eaten raw,
and some cooked with a variable pal-
atability and variable periods of de-
terioation. May be cooked with com-
binations of fish, shrimp, meat.

Not of great, if any, economic impor-
tance; but is of intriguing interest, both
because of its association with its
host and its specific nature. It is also
of interest because of its seasonal ap-
pearance and its unique—but not obvi-
ously functional—sac-like form.

Chorda with diameter of a lead pencil
and a length of up to 20 feet has com-
mon name of "mermaid's fishing line." Most members of this family have a
branched, flat-bladed line, but the
ropelike character here noted. Young
plants adhere to mounting paper be-
cause of their mucilaginous nature.

Massed growth of plants provides
needed shelter for many small marine
animals that serve as a basic food for
fishes. There does not seem to be an
important specific economic use for
this species, but it plays a part in the
general roles filled by its relatives.

Wave violence and alternating expo-
sure to sun and dryness, and submer-
sion in sea water limit the kinds of
plants and animals that can live where
the sea cabbage prospers, but its tough
holdfasts and overlapping "leaves" pro-
vide the necessary conditions for the
growth of other marine plants.

Probably of little or no economic im-
portance, but a uniquely typical plant
for the wave-beaten rocky exposures
of its habitat. Undoubtedly provides
some food and shelter for animals
that share the same terrigenous and
appeals to artists depicting its habitat.
<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>RANGE AND HABITAT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pompon</strong></td>
<td>Found from British Columbia to northern Baja California, particularly in deep crevices under water where waves are violent. Distribution is apparently limited to shores of the Gulf of California. It is found at lower tide level, and is considered a deep-water resident.</td>
</tr>
<tr>
<td>Pterygophoro californica</td>
<td>Phaeophyceae, Laminariales, Alariaceae</td>
</tr>
<tr>
<td><strong>Feather Boa</strong></td>
<td>From British Columbia to Point Conception in central California between 2-foot and mean low tide levels on rocky beaches or shores, with plants reaching a length of more than 20 feet. Plants are deep chocolate-brown, and are largely covered with tubercles. The sporophytes are perennial.</td>
</tr>
<tr>
<td>Egregia menziesii</td>
<td>Phaeophyceae, Laminariales, Alariaceae</td>
</tr>
<tr>
<td><strong>Woody Chain Bladder</strong></td>
<td>Ranges from the State of Washington south along the coast to Lower California in the Baja California region, and is found between the mean low tide level and the 1 ½-foot tide levels. Species belongs to family which sagassesum is most closely related which is basis of Sargasso Sea plants.</td>
</tr>
<tr>
<td>Cystoseira osmundacea</td>
<td>Phaeophyceae, Fucales, Sargassaceae</td>
</tr>
<tr>
<td><strong>Common Coraline</strong></td>
<td>A native plant of California shores, and found along our Atlantic coast north of New York. Several species are all characterized by the stony encrustation of the fronds. Some of these are pink, and are found from the intertidal area and the tide pools out to rather deep water.</td>
</tr>
<tr>
<td>Corallina officinalis</td>
<td>Phaeophyceae, Cryptonemiiales, Corallinaceae</td>
</tr>
<tr>
<td><strong>Leaf Coral</strong></td>
<td>Ranges from Oregon to southern California with an abundance of species in many places. This species is found growing on shells and rocks, from between the mean low tide level to the minus 1 ½-foot level. It is related, of course, to the coralline just discussed.</td>
</tr>
<tr>
<td>Bossea orbigniana</td>
<td>Rhodophyceae, Cryptonemiiales, Corallinaceae</td>
</tr>
<tr>
<td><strong>Ahnfelt's Seaweed</strong></td>
<td>This species ranges on Pacific coast from Alaska to Carmel Bay in California, and on Atlantic coast from New York to Massachusetts. It was originally described from England. The deep parpillo in black color strengthens the impression that the plant is not organic but rather of a metallic nature.</td>
</tr>
<tr>
<td>Ahnfeltia plicata</td>
<td>Rhodophyceae, Gigartinales, Phyllophoraceae</td>
</tr>
<tr>
<td><strong>Iridescent Seaweed</strong></td>
<td>Ranges from northern Washington to central California, with a half-dozen species on continental United States' Pacific coast. Grows on rocks exposed to strong surf at 1- to 2-foot tide levels. Some species are found locally in great abundance.</td>
</tr>
<tr>
<td>Irrophycus coriaceum</td>
<td>Rhodophyceae, Gigartinales, Gigartinaeace</td>
</tr>
<tr>
<td><strong>Pottery Seaweed</strong></td>
<td>Found growing on rocks near shore, on plants, on wood, on shells, or almost anywhere. It grows from tidal to moderately deep waters in almost all seas of the world. Found throughout the year. Found in the Tropics, and ranges from Florida to Newfoundland.</td>
</tr>
<tr>
<td>Ceramium rubrum</td>
<td>Rhodophyceae, Ceramiaceae, Ceramiaceae</td>
</tr>
<tr>
<td><strong>Chondria</strong></td>
<td>Genus is represented on both Atlantic and Pacific coasts of North America, with this species growing on shells and rocks just below the low tide line and usually in sheltered areas. It ranges from the Tropics to Massachusetts on Atlantic coast, and has two most abundant species in southern California.</td>
</tr>
<tr>
<td>Chondria tenuissima</td>
<td>Rhodophyceae, Ceramiaceae, Rhodomelaceae</td>
</tr>
</tbody>
</table>
Lateral blades bear spore cases that begin fruiting in October and continue until the blades are all shed by winter. From these spores develop the gametophytes typical of the family, and from the gametophytes develop the conspicuous plants considered here.

Some of the lateral sporophylls may be completely covered with spore cases, but the spore-bearing and the sterile branches are not always easily distinguished without skill and opportunity for study. Gametophytic stages are typical and inconspicuous.

This is a perennial, at least as far as the central stem is concerned; but the terminal blades are shed and leave scars that may be used to determine the age of the plant. In winter, everything is shed except the supporting stalk. Some Northwest plants live to the age of 13 years at least.

Spore-producing such as these are not always easily distinguished from the supporting stalk. Some Northwest plants live to the age of 13 years at least.

In part, because of the great volume of this plant, and because so much of it can be harvested with convenience, the plant is used commonly as a fertilizer. Fertilizing value is like that of barnyard manure, contains more potassium, about the same amount of nitrogen and less phosphoric acid.

The common name pompon refers to common age because it is a mass bearing an aggregation of streamers at its end. Plants provide a degree of food and anchorage for the many other species that are common to so many plants—and other organisms, for that matter.

The plant provides food and shelter for some marine animals that share its habitat, and it has an intriguing variation in its body structure. It differs pleasantly from the monocotyledons in being typical of many other uses may be rewarding. Possible uses as food, as fertilizer, as medicine, should be investigated.

During the Atlantic area, this group is well represented by the genus Fucus, so commonly considered in courses in botany, and also by the gulfweed Sargassum. Both of these plants were considered in detail in the thirty-eighth insert on Marine Algae.

Because of the volume of material produced by this alga, its potential usefulness, and its relatively wide distribution, studies toward new uses may be rewarding. Possible uses as food, as fertilizer, as medicine, should be investigated.

Plants are not mucilage-covered, as are so many marine algae. They are found throughout the year, and are so variable that they have tempted many students to proposing a variety of names for new species. Names do not usually survive critical studies.

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In plants of this type, lime is deposited to a greater extent where there is a good exposure to wave action, and the amount of lime in the plants in summer is less than it is in winter. Lime deposit is probably associated with removal of carbon dioxide by action of photosynthesis.

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In 1930, Russians began producing Russian agar from Alkafella, which they claim equals, and in some respects exceeds, the usefulness of the best grade agar produced from other sources. This may turn out to be a valuable use of this and related algae.

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nature IN THE SCHOOL

During the year 1873, the famous scientist Louis Agassiz established a summer school on the island of Penikese, off the New England coast. In this marine environment, one of the greatest teachers of biology taught a group of from fifty to sixty adults.

Many of his study group returned to homes that were far-removed from an intertidal strip, to prepare books to be used as guides in the teaching of biology. Much of the material that appeared in the resulting books concerned the organisms observed and studied on the Penikese intertidal strip; and, perhaps because of this, there are many schools today that, for study purposes, use marine plants and animals similar to those studied at Agassiz' summer school.

Biological supply houses, also, offer seaweeds similar to those studied by the Agassiz group in 1873; and, indeed, the study of seaweeds in school is currently recognized as appropriate, even if such a study results in the neglect of the locally available algae.

While biological houses can supply excellent marine material for study in those schools that are far removed from tidal strips, there are probably many schools with access to the sea that are not making the best use of the available opportunities. Here, then, are some study suggestions for classes or individuals.

Select some rock, pool, or unit of sandy beach, and keep a record of the changes in its population during the course of a single year. Record the temperature of the area at regular intervals through a twenty-four-hour cycle, to show variations between low and high tides. Make a record of the length of time a selected area is submerged, and the length of time during a day when it is not touched by sea water. Note the effect of submergence and exposure on the bases and tips of the marine algae that are present. Make a survey of the animals present at the surface of the plant cover surface, and yet another of those found close to the bottom of the plant cover. In what ways do they differ?

From direct observation of the material found at one locality, indicate which of the organisms present are annuals, and which are longer-lived. If special reproductive structures are to be seen on parts of the plants, make a record of the months in which they are the most obvious. If possible, make accurate laboratory studies of the events that take place in the reproductive structures.

Observe whether animals feed on the algae in the test area, and collect specimens that have been partly eaten. Examine the plants and their closely associated animals, to ascertain whether the associations are constant or varied. Do shore birds, feeding along a strip of land covered by marine algae, confine their search for food to open and exposed rocks, or to algae-covered earth? Make a study of any peculiar feeding habits of the local shore birds, and the relation of these habits to the local marine algae.

Make a herbarium of local marine algae, if such plants are available. These plants may often fasten themselves to herbarium sheets simply by means of the mucilage that is found on them. If the herbarium sheet is submerged in a large pan partly filled with water, and the algae floated into position over the paper, the surplus water may be drawn off and the algae allowed to dry "in position" on the sheet. This permits the arrangements of strands of fine algae, so that the strands do not "bunch up" and form an unsightly mass. Some students have employed the technique of covering the wet algae, in proper position, with waxed paper. The mucilage will not stick to the waxed paper, and the material may then be dried through the mounting paper.

After a list of the local marine algae has been made, consult the available laboratory manuals to ascertain which of the local species have been considered. The student may be surprised to find how few of the conspicuous local species are represented in such a list. He may also be surprised to learn of the considerable detail devoted to other species. A study such as this is certain to suggest areas in which individual research will be highly profitable and of extraordinary interest.

It seems reasonable, therefore, to suggest that a school biology class should be prepared to depart from the routine prescribed by texts and laboratory manuals at least once, to explore a virgin field. The study of the marine algae and their associates will offer a rich opportunity in this respect.

The graceful positions assumed by many of the marine algae might provide inspiration for artistic young students. Particularly striking specimens may be photographed, and used for making designs of a most attractive appearance. The elastic nature of the average marine algae, which can survive the whipping and lashing of storm waves, may also suggest that survival of life is sometimes best achieved by a course of non-resistance to superior forces up to a certain point, at least!
SKY REPORTER

By Simone Daro Gossner

In all its complexity, the system of Eudoxus' homocentric spheres (see February article) failed to account for one observed fact, the inequality of the seasons. The astronomer Callippus, born in Cyzicus, ca. 330 B.C., had become aware of this discrepancy and attempted to modify Eudoxus' theory in order to account for the length of the seasons as well. His solution was merely to increase the total number of spheres, which he brought to thirty-three. The famous Aristotle may have worked with Callippus for a while: although he shared the latter's acceptance of homocentricism, his approach was different.

Aristotle believed that all celestial motions obey a single moving force and, therefore, that all must be interrelated. In other words, instead of considering a separate group of spheres for each of the planets, as did Eudoxus, Aristotle held that the spheres of Mars, for example, are subject to all the motions of Jupiter's spheres, which in turn are connected with those of Saturn. Since, however,
there is no evidence of such connection in the apparent motions of these planets, he had to introduce compensating spheres to eliminate spurious motions. This needlessly cumbersome system required fifty-seven spheres!

There was another basic difference between the cosmologies of Eudoxus and Aristotle. The former conceived homocentric spheres as purely mathematical representations (much in the same way that we think of gravitation, for example). Aristotle, on the contrary, thought of these spheres as physical entities. To him they were hollow bodies—made of crystal, since they were transparent.

In spite of the extraordinary influence of Aristotle’s teachings, which would be felt for nearly two thousand years, a few astronomers of his time had come to understand that the whole notion of homocentricism was incompatible with observational evidence. In particular, they had correctly interpreted the variable brightness of Venus and Mars and their corresponding variation in the distance of these planets from earth. One of them, Heracleides Ponticus, went so far as to suggest that Venus revolves around the sun. A few decades later, ca. 280 B.C., Aristarchus of Samos designated the sun as the center of all planetary motions—including that of the earth. This predecessor of Copernicus did not fare too well, unfortunately. His views were so contrary to the evidence of the senses that he had only a small following [after all, do you feel the earth rotating and traveling in space?]. The next centuries saw a complete return to the concept of a fixed earth.

The four hundred years following Aristarchus represent the crucial period during which the system that would bear the name of Ptolemy slowly began to crystallize. The observations of Hipparchus—who lived at Rhodes in the second century B.C.—had revealed details of celestial motions that could no longer be explained by the homocentric theory. The astronomers of that period did not think of abandoning the concept of circular orbits, but they accounted for the varying distances of planets by offsetting these orbits with respect to the earth. “Loops” in the apparent motions of planets were explained by combining two or more circular motions. Various refinements were introduced over the years, until Ptolemy organized the theories of his predecessors into one coherent system and described it in his monumental work, commonly known as the Almagest.

History tells us little about Claudius Ptolemy beyond the fact that he was of Greco-Egyptian origin, and that he lived at Alexandria in the second century of the Christian Era. He was an astronomer, mathematician and geographer of great ability. His explanation of planetary motion which we call the Ptolemaic system, is extremely complex.

In his time, the distances from earth to the various planets, the sun and the moon, were not well enough known for Ptolemy to place them in their correct sequence—supposing, of course, that the earth was at the center of the system. He placed it instead in increasing order of the apparent periods of revolution, as viewed from the earth. Thus, from the earth outward, the sequence read: the moon, Mercury, Venus, the sun, Mars, Jupiter, and Saturn. This arrangement ignores the fact that Mercury and Venus can, at times, be farthest away from the earth than is the sun. It is true that this fact had been surmised by some of Ptolemy’s predecessors, but the latter’s strict adherence to geocentricism ruled out the possibility. In Ptolemy’s sequence, Venus and Mercury are called inferior planets, meaning that they are closer to the earth than is the sun; conversely, Mars, Jupiter, and Saturn are called superior planets. These terms are still in use today, even though they have lost their Ptolemaic significance.

The principles of the Ptolemaic system can be illustrated best in the case of one of the superior planets (i.e., those beyond the orbit of Mars). The observations of Hipparchus and Ptolemy showed that the orbit of Jupiter was a tilted ellipse. Ptolemy’s use of spheres to represent planets was clearly limited to the case of the earth. Ptolemy’s system, which explained the movements of the sky, as well as the apparent movements at sea, was an extremely complex but successful effort to reconcile observation with the ancient belief in a fixed earth.
illustration at left, above). The planet (small black dot) is thought to revolve with constant speed around a small circle, called the epicycle. The center of the epicycle, in turn, is assumed to revolve around a larger circle (with its center at C) called the deferent. The earth is located at D; thus the deferent is off-center with respect to the earth, and is sometimes called the eccentric for that reason. In order to conform with data of observation, the center of the epicycle should move at varying speed along the deferent. This, however, is contrary to the principle of uniform speed so dear to the ancients; principle and observation are reconciled by the introduction of still a third circle, called the equant (outermost circle, with center at H), with the assumption that a point on the line joining H to the center of the epicycle moves along the equant at constant speed. Inasmuch as H does not coincide with the center of the deferent, the resulting speed of the epicycle along the deferent becomes variable.

Although the Ptolemaic system was rooted in the cumbersome concept of a completely static earth, it accounted satisfactorily for observed planetary motions within the limits of accuracy of the epoch. The loops in apparent orbits were explained by motion along an epicycle. The variable speed along the orbit was justified by the equant. Other phenomena, such as eclipses, were understood correctly, as the diagram at the foot of page 45 serves to demonstrate.

During the Dark Ages, European science underwent a steady decline as barbarian invasions isolated the scholars there from the major sources of classic tradition. Astronomy reverted to empirical concepts and astrological nonsense. Fortunately, the continuity of Greek science was assured through the brilliant Arab civilization that flourished during that period. Toward the middle of the twelfth century, European scholars began to rediscover many of the important Greek astronomical works in their Arabic translations. Among them, Gerard of Cremona published a translation of Ptolemy's *Almagest* at Seville in 1175. A century later, King Alfonso X of Castile published a new set of astronomical tables, based on a modification of the Ptolemaic system, which sought to account for the observed, slow displacement of the celestial pole (see illustration at center of page, above).

Given this new impetus, Ptolemaic astronomy flourished again and reached its greatest moments in the fifteenth and sixteenth centuries, particularly at the hands of Georg Peurbach (1423-1461) of Vienna and his disciple Johann Müller (1436-1476) of Königsberg, who became known under the name Regiomontanus. The invention of the printing press in about 1440 permitted unprecedented diffusion of their works. In fact, Regiomontanus himself established his own publishing house. The numerous editions of astronomical treatises of that period bear witness to the considerable popular interest these works seem to have aroused.

From the physical standpoint, it appears that Ptolemy was reluctant to discard the views of Aristotle concerning material spheres. He tried, not too successfully, to give a physical equivalent to his mathematical epicycles and deferents, by assuming that the motions along these circles are caused by the existence of an ethereal fluid encased in solid orbs—one rolling within the other. This idea seemed hardly acceptable because the orbs pertaining to various planets would necessarily overlap and it was thought inconceivable that the same fluid could impart different motions to different objects. Renaissance astronomers, however, removed this difficulty by substituting doughnut-shaped bodies for the spherical orbs. In this way, the system belonging to each planet could be kept from penetrating any of the others. A sixteenth-century representation of this is shown at right, above, in the case of the sun (white epicycle overlapping black deferent).
THE SKY IN MARCH

From the Almanac:

<table>
<thead>
<tr>
<th>Phase</th>
<th>Date</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Moon</td>
<td>March 2</td>
<td>8:35 A.M., EST</td>
</tr>
<tr>
<td>Last Quarter</td>
<td>March 9</td>
<td>9:58 P.M., EST</td>
</tr>
<tr>
<td>New Moon</td>
<td>March 16</td>
<td>1:51 P.M., EST</td>
</tr>
<tr>
<td>First Quarter</td>
<td>March 23</td>
<td>9:49 P.M., EST</td>
</tr>
</tbody>
</table>

The sun will be at the vernal equinox on March 20 at 3:32 P.M., Eastern Standard Time. On that date, spring will begin in the Northern Hemisphere.

For the visual observer:

Mercury, in the morning sky, will reach its greatest western elongation on March 20, and will be favorably placed for observation for a few days on either side of that date. It will rise at the southeast at about 5:30 A.M. on March 1, and at 5:00 A.M. on March 15 and 31.

Venus, in Pisces, will be seen as an evening star throughout the month of March. It will reach its greatest brilliancy (—4.3 magnitude) on March 5, and will be a very conspicuous object high above the western horizon in early evening. Its brightness will fade gradually from —4.2 magnitude on March 15 to —3.7 on March 31. The planet will set at approximately 9:30 P.M. on March 1, at 9:00 P.M. on March 15, and at 8:00 P.M. on March 31.

Mars, in Gemini, will be nearly overhead at dusk during the entire month. It will set in the northwest at about 3:15 A.M. on March 1, at 2:30 A.M. on March 15, and at 2 A.M. on March 31. Its brightness will continue to decrease from +0.3 magnitude on March 1 to +0.9 on March 31.

Jupiter, in the morning sky (—1.6 magnitude), will be found between Sagittarius and Capricornus, and will stand out in the southeastern sky at sunrise. The planet will rise at approximately 4:40 A.M. on March 1, at 3:40 A.M. on March 15, and at 2:50 A.M. on March 31.

Saturn, in Sagittarius (—0.9 magnitude), will also be in the morning sky, a few degrees west of Jupiter—with which it will make a noteworthy pair. These two planets will rise a few minutes apart—Saturn preceding—during the entire month of March (see times above).

Lunar Eclipse:

An extensive partial eclipse of the moon will take place during the early morning hours of March 2. Observers on the east coast will get only a glimpse of the penumbral phase, which will start at 5:32 A.M., EST, with an almost imperceptible lessening of the moon’s brightness. In those locations, unfortunately, the moon will set a few minutes before the beginning of the umbral phase. Elsewhere in the country, observers will be able to see at least the first encroachment of the earth’s shadow on the disk of the moon (5:51 A.M., CST, and the equivalent in other time zones). Most favored will be the West Coast, where the maximum eclipse will be seen at 5:23 A.M., PST. But even there, the moon will set partially eclipsed.

The magnitude of this eclipse at maximum phase will be 0.8. This means, by definition, that eight-tenths of the lunar diameter will be covered by the earth’s shadow, and is the conventional way of expressing the extent of an eclipse. Observers with a small telescope can follow the progress of the shadow across the various features of the lunar surface and record the time of their disappearance.

On the preceding pages, Mrs. Gossner offers the third in her 1961 series on the growth of cosmological concepts.
The Lives and Times of Mij and Edal

Young otters from Iraq and Nigeria adapt to Highland waters
EARLY IN THE NEW YEAR of 1956, I traveled with Major Wilfred Thesiger to spend two months or so among the little-known marshmen, or Ma’dan, of southern Iraq. By then it had crossed my mind, though with no great emphasis, that I should like to keep an otter and that my isolated home in the western Highlands—ringed by water just a stone’s throw from its door—would be an eminently suitable spot for this experiment. I mentioned this casually to Wilfred soon after the outset of our journey and he, as casually, replied that I had better get one in the Tigris marshes before I came home, for there otters were as common as mosquitoes, and were often tamed by the Arab “people of the reeds.”

A few days after our marsh journey had ended, I went to Basra—where the British Consul very kindly took me in as a guest—to collect and answer mail from home. As I should have expected, the mail was late. Returning to the Consulate one afternoon, I found that the mail had arrived at last. I carried it to my bedroom to read and there, squatting on the floor, were two marsh Arabs; beside them lay a well-filled sack that squirmed from time to time.

They handed me a note from Thesiger. “Here is your otter, a male and weaned... Give Ajram a letter to me saying it has arrived safely...”

With the opening of that sack began a phase of my life that has not yet ended and may, for all I know, not end before I do. It is, in effect, a shorthand to otters.

The creature that emerged, not greatly disconcerted, from this sack on to the sparsity tiled floor of the Consulate bedroom did not at that moment resemble anything so much as a very small medievally conceived dragon. From the head to the tip of the tail he was coiled with symmetrical pointed scales of mud armor, between whose tips was visible a soft velvet fur like that of a chesed-brown mole. He shook himself, and I half expected this aggressive camouflage to disintegrate into a cloud of dust but it remained unaffected by his maneuver, and in fact it was not for another month that I contrived to remove the last of it and see him, as it were, in his true colors.

For the first twenty-four hours, Mij—an otter whom I named after a local sheik—was not hostile or friendly, he was simply aloof and indifferent, choosing to sleep on the floor as far from my bed as possible, and to accept food and water as though they were things that had appeared before him without human assistance. The food presented a problem, for it did not immediately occur to me that the marsh Arabs had almost certainly fed him on rice scraps supplemented only by such portions of fish as are indigestible to humans. The Consul-General sent out a servant to buy fish, but this servant’s return coincided with a visit from Robert Angusly, the Crown Prince’s game warden, who entertained a passionate interest in natural history. Angusly told me that none of the fishes that had been bought was safe for an animal, for they had been poisoned with digitalis, which, though

By Gavin Maxwell

MISHUNG MOUNTAINS shadow author’s dinghy, which is moored in shallows of the island-studded west Scotland bay, opening out to wild Atlantic beyond.
harmless to a human in this quantity, he felt certain would be dangerous to a young otter. He offered to obtain me a daily supply of fish that had been taken with nets, and every day thereafter he brought half a dozen or so small reddish fish from the Tigris. These Mij consumed with gusto, holding them upright between his forepaws, tail end uppermost, and eating them with five crunches of the left-hand side of the jaw alternating with five crunches on the right.

The otter and I enjoyed the long-suffering Consul-General's hospitality for a fortnight. The second night, Mij came on to my bed in the small hours and remained asleep in the crook of my knees until the servant brought tea in the morning. During that day, he began to lose his apathy and take a keen—much too keen—interest in his surroundings. I fashioned a body-belt for him and took him on a lead to the bathroom, where for a half-hour he went wild with joy in the bath water, plunging and rolling in it, shooting up and down the length of the bath underwater, and making enough slosh and splash for a hippo. This, I was to learn, is a characteristic of otters; every drop of water must be, so to speak, extended and spread about the place; a bowl must be overturned, or, if it will not overturn, be sat in and splashed in until it overflows. Water must be kept on the move and made to do things; when static, it is as wasted and provoking as a buried talent.

There is a patron saint of otters, St. Cuthbert (the eider duck, too, shares his patronage), and there exists an eyewitness account of his converse with them:

"As was his habit, at night while other men were taking their rest, Cuthbert would go out to pray; and after long vigils kept far into the night, he would come home when the hour of common prayer drew near. One night, a brother of this same monastery saw him go silently out, and stealthily followed on his track, to see where he was going or what he would do. And so he went out from the monastery and, his spy following him, went down to the sea, above which the monastery was built; and wading into the depths till the waves swelled up to his neck and arms, kept his vigil through the dark with chanting voiced like the sea. As the twilight of dawn drew near, he waded back up the beach, and kneeling there, again began to pray; and as he prayed, straight from the depths of the sea came two four-footed beasts which are called by the common people otters. These, prostrate before him on the sand, began to busy themselves warming his feet with pantings, and trying to dry them with their fur; and when this good office was rendered, and they had his benediction they slipped back again beneath their native waters. He himself returned home, and sang the hymns of the office with the brethren at the appointed hour."

It is apparent to me now, that whatever other saintly virtues St. Cuthbert possessed, he well merited canonization by reason of his forbearance alone. I know all about being "dried" by otters. I have been dried by them.

Mr. Maxwell is a free-lance writer, portrait painter, and naturalist, from whose book, Ring of Bright Water, just published by E. P. Dutton and Co., this otter history is excerpted.
more times than I care to remember. Like everything else about otters, it takes place the wrong way round, so to speak. When one plays ball with a puppy, one throws the ball and the puppy fetches it back and then one throws it again; it is all comparatively restful and orderly. But when one plays ball with an otter the situation gets out of hand from the start; it is the otter who throws the ball—to a remarkable distance—and the human who fetches it. With the human who at the beginning is not trained to this, the otter is fairly patient, but persistent and obstinate refusal meets with reprisals. The same upside-down situation obtains when being dried by otters. The otter emerges tempestuously from the sea or the river or the bath, as the case may be, carrying about half a gallon of water in its fur, and sets about drying you with a positively terrifying zeal and enthusiasm. Every inch of you requires, in the view of a conscientious otter, careful attention. The otter uses its back as
Although all four feet were webbed, Mij was remarkably dexterous, would spend hours juggling small objects, or rolling them easily between forepaws.

The scant zoological literature that had accompanied me to Iraq made it plain that the only known otter of the Mesopotamian marshes was the Persian subspecies of the common European otter, *Lutra lutra*. In a village of the marshes between the Tigris and the Persian frontier I had bought two otter skins. Both were, apart from any possible scientific interest, objects of fascination for they had been “easy” skinned, the whole carcass having been removed without a single incision, through the mouth. One of these skins belonged to the Persian subspecies; the other contrast heightened by juxtaposition was plainly of Mij’s race, a mud larger and darker creature, whose fur was short and shiny and the color of milkless chocolate.

While in London on my way to the Highlands, I telephoned to the British Museum (Natural History) in Cromwell Road, and the same afternoon Mr. Robert Hayman arrived at my flat to examine the two skins and Mij. There is in the serious zoological world an unwillingness for commitments that must rival the most cautious consulting physicians. Hayman was far too competent a zoologist, far too encyclopedic in his knowledge, to have been unaware in those first moments that he was looking at a ski and a living animal from a habitat that made the race quite unfamiliar to him. But he did not betray it. He too such measurements as Mij would permit, examined him closely, peered at his formidable array of teeth, an left, bearing the two skins for comparison with a Museum series.

In due course, after the precision-painstaking processes of the taxonomic world, Mij’s new race was proclaimed, Hayman summoned me to the Museum to see the cabinets of otter skins from all over Asia, when the Mij-like one of mine lay, unfiled and conspicuously different from any other, in a drawer by itself but in apposition to its nearest relatives. These, various subspecies - *Lutrogale*, a short-coated otter with...
flat underside to the tail, ranged over most of eastern Asia; according to their geographical race they were of a variety of hues from pale sandy to medium brown, but none had been recorded west of Sind, in India, and none resembled mine in color.

There are very few people, and even fewer amateur zoologists, who stumble upon a sizable mammal previously unknown to science; in the nursery world of picture books of birds and beasts the few who had given their own names to species—Steller’s eider and sea eagle, Sharpe’s crow, Humboldt’s woolly monkey—had been surrounded for me with an aura of romance. Now, when Hayman suggested that the new otter should bear my name, something small and shrill from the nursery days shouted inside me that I could be translated into the hierarchy of my early gods and wear, however perilously, the halo of a creator. (“Can I have it for my own?” we used to ask when we were small. “For my very own?” Here, surely, was an animal of my own, to bear my name; every animal that looked like it would always bear my name for ever and ever, unless some odious taxonomist of the future, some leveler, some jealous, dusty scribe of the backroom and the skeletons, were to plot against me and plan the destruction of my tiny, living memorial.)

So Mij and all his race became Lutra gal perspicillata maxwelli, and though he is now no more, and there is no ostensible proof that there is another living specimen in the world, I had realized a far-off childish fantasy, and there was a Maxwell’s otter.

When I think of early summer in the western Highlands, a single enduring image comes forward—that of wild roses against a clear blue sea. They are not the pale, anemic flowers of the south, but a deep, intense pink that is almost a red; it is probably the only flower of that color, and it is the only flower that one sees habitually against the background of the ocean, free from the green stain of summer.

Into this bright landscape Mij moved and took possession with behavior that communicated delight as clearly as any articulate speech could have done, his alien but essentially appropriate entity occupied and dominated every corner of it, so that he became for me the central figure among the host of wild creatures with which I was surrounded. The waterfall, the bourn, the white beaches and the islands—his form became the familiar foreground to them all.

At the beginning, while I was still imbued with the caution and forethought that had so far gone to his tending, Mij’s daily life followed something of a routine; this became, as the weeks went on, relaxed into a total freedom at the center point of which my house remained Mij’s holt, the den to which he returned at night, and in the daytime when he was tired. But this emancipation, like most natural changes, took place so gradually and unobtrusively that it was difficult for me to say at what point the routine had stopped.

Mij slept in my bed and would wake with bizarre punctuality at exactly twenty past eight in the morning. Having woken, he would come up to the pillow and nuzzle my face and neck with small attenuated squeaks that seemed to me of pleasure and affection. If I did not rouse myself very soon, he would set about getting me out of bed. This he did with what impressed me as the business-like, slightly impatient efficiency of a nurse dealing with a difficult child. He began by going under the bedclothes and moving rapidly up and down the bed with a high-hunching, caterpillar-like motion that gradually untucked the bedclothes from beneath the sides of the mattress. This achieved, he would redouble his efforts at the foot of the bed, where the sheets and blankets had a firmer hold. When everything had been loosened up to his satisfaction, he would flow off the bed on to the floor—except when running on dry land the only appropriate word involved “hiding” under a carpet until a human passed near and then shooting out with apparently triumphant squeak.
for an otter's movement is flowing; they pour themselves, as it were, in the direction of their objective—take the bedclothes between his teeth, and, with a series of violent tugs, begin to yank them down beside him. Left thus comfortless and bereft both of covering and of dignity, there was little option but to dress, while Mij looked on with what seemed to me an all-that-shouldn't-really-have-been-necessary-you-know sort of expression. Otters usually get their own way in the end; they are not dogs, and they coexist with their fortunate human hosts rather than being owned by them.

In the sea, Mij achieved his true, breath-taking powers: until he came to Scotland he had never swum in deep waters, for the lakes and lagoons of his native marshes are rarely more than a fathom or two deep. He would swim beside me as I rowed in a little dinghy, and in the glass-clear waters of Camusfearna Bay, where the white shell sand alternates with sea tangle and outcrops of rock, I could watch him as he dived down, down, down through fathom after fathom to explore the gaudy sea forests at the bottom with their flowered shell glades and mysterious, shadowed caverns. He was able, as are other otters, to walk on the bottom without excessive buoyance, for an otter swims habitually underwater and does not dive with full lungs, depending for oxygen—we must presume, in the absence of knowledge—upon special adaptations of the circulatory system. The longest that I ever timed Mij below the surface was almost six minutes, but I had the impression that he was in no way taxing his powers, and could greatly have exceeded that time in emergency. Normally, however, if he was not engaged, he would return to the surface every minute or so, breaking for only a second, with a forward diving roll like that of a porpoise. Swimming at the surface, as he did if he wanted to keep some floating object in view, he was neither very fast nor graceful, using a laboring dog paddle in amazing contrast to his smooth darting grace below water. For hour he would keep pace with the boat, appearing now on this side and now of that, sometimes mischievously seizing an oar with both arms and dragging it over, and from time to time bouncin;
inboard with a flurry of water, momentarily recalled to his mission of "drying" any person at hand.

Mij himself caught a number of fish on his daily outings; and week by week, as his skill and speed grew, their size and variety increased. In the bourn he learned to feel under stones for eels, reaching in with a paw and averted head. Meanwhile, I learned to turn over the larger stones for him, so that after a time he would stand in front of some boulder too heavy for him to move, and chitter at me till I came and lifted it for him. Often, as I did this, an eel would streak out from it into deeper water and Mij would fire himself after it like a brown torpedo beneath the surface. Near the edge of the tide he would search out the perfectly camouflaged flounders until they shot off with a wake of rising sand grains like smoke from an express train. Farther out in the bay he would kill an occasional sea trout; these he never brought ashore, but ate them while he was treading water, and I thought a little wistfully of the Chinese who are said to employ trained otters to fish for them. Mij, I thought, with all his delightful camaraderies, would never offer me a fish. I was wrong, but when at last he did so it was not a sea trout but a flounder. One day he emerged from the sea on to the rock ledge where I was standing and slapped down in front of me a flounder a foot across. I took it that he had brought this for congratulation, for he would often bring his choicer catches for inspection before consuming them, so I said something encouraging and began to walk on. He hurried after me and slammed it down again with a wet smack at my feet. Even then I did not understand, assuming only that he wished to eat in company, but he just sat there looking up and chittering at me. I was in no hurry to take the gesture at its face value. One of the most aggressive actions one can perform to a wild animal is to deprive it of its prey, but after perhaps half a minute of doubt, while Mij redoubled his invitation, I reached down slowly and cautiously for the fish, knowing that Mij would give me vocal warning if I had misinterpreted him. His expression seemed one of plainest approval when I picked it up and began a mimic of eating it; then he plunged off the rock into the sea and sped away a fathom down in the clear water.

Watching Mij in a rough sea—and the equinoctial gales at Camusfearna produce very rough seas indeed—I was at first sick with apprehension, then awed and fascinated, for his powers seemed little less than miraculous. During the first of the gales, I remember, I tried to keep him to the rock pools and the

Eadal's silvery colored head and her yellow-white throat and chest differed sharply from Mij's darker hue. Pools in rocks supplied her with butterfish.
more sheltered corners, but one day his pursuit of some unseen prey had taken him to the seaward side of a high, dry reef at the very tide’s edge. As the undertow sucked outward he was in no more than an inch or two of marbled water with the rock at his back, crunching the small fish he had caught; then, some forty yards to seaward of him I saw a great snarling comber piling up higher and higher, surging in fifteen feet tall and as yet unbreaking. I yelled to Mij as the wave towered darkly toward him, but he went on eating and paid no heed to me. It curved over and broke just before it reached him; all those tons of water just smashed down and obliterated him, enveloping the whole rock behind in a booming tumult of sea. Then as the sea drew back in a long hissing undertow I saw, incredulously, that nothing had changed; there was Mij still lying in the shallow water, still eating his fish.

Whenever I missed Mij from his accustomed haunts I would go first to my waterfall, for there he would spend long hours alone, chasing the one large trout that lived in the big pool below the falls, catching elvers, or playing with some floating object that had been washed down. Sometimes he would set out from the house carrying a ping-pong ball, purposeful and self-engrossed, and he would still be at the waterfall with it an hour later, pulling it underwater and letting it shoot up again, rearing up and pouncing on it, playing his own form of water polo, with a goal at which the human onlooker could but guess. Once, I remember, I went to look for him there and at first could not find him; then my attention was caught by something red in the black water at the edge of the foam, and I saw that Mij was floating on his back, apparently fast asleep, with a bunch of scarlet rowanberries clasped to his chest with one arm. Such bright objects as these he would often pick up on his walks, and carry them with him until some rival attraction supplanted them. I never performed any tests to define his degree of color vision, but whether by chance or selection his preferred playthings were often of a rather garish hue.

Mij had been with me a little over a year when—wandering freely in his Highland range—he was killed by a willess Scot who mistook him, he claimed, for a wild otter. After the worst of my grief, I unsuccessfully sought another otter companion.

After three disappointments, I decided to rear a native otter cub in Scotland, and with that end in view I returned to Camusféarna, for a prolonged stay, in the spring of 1939. I had been there only a week when there occurred a coincidence so extravagant, partaking so insolently of the world of fiction, that had it been unwitnessed or in another land I should hesitate to record it.

On April 19 I motored to the railway station, thirty-odd miles away, to meet an arriving guest. We returned to a hotel for a “wee dram” before setting off for Camusféarna. We sat in the sun lounge that overlooks the sea, but we were well back from the window, and out of sight of the gravel sweep beyond the glass. Suddenly the hall porter came running over.

“Mr. Maxwell!” he called. “Mr. Maxwell! Come quick to the door and tell me what’s this strange beast outside—quick!”

Four people were walking past the hotel, making for a car parked near to the jetty. At their heels lolloped a large, sleek otter, of a species that I had never seen, with a silvery colored head and a snow-white throat and chest. I had a deep feeling of unreality, of struggling in a dream.

I rushed up to the party, and began to jabber, probably quite incoher-
Edal, it was breaking my heart..."

We were sitting on the steps of the hotel by this time, and the otter was nuzzling at the nape of my neck—that well-remembered, poignantly touch of hard whiskers and soft face-fur.

Ten days later, Edal became mine, and there was once more an otter at Camusfearna, playing in the bourn and sleeping before the hearth.

By far the strangest and most captivating aspect of Edal was that of her forepaws. Unlike Mij, whose forepaws were, despite the dexterity he contrived with them, true paws with wide connecting webs between the digits, hers were virtual monkey hands—unwebbed, devoid of so much as a vestige of nail, and nearly as mobile as a man's. With them she ate, peeled hard-boiled eggs, picked her teeth, arranged her bed, and played for hours with any small object that she could find. She would lie upon her back passing things from hand to hand or, occasionally, to the less adept grip of her webbed but almost nailless hind feet, working always with two or more objects at a time, gazing fixedly at them all the while, as though these extremities of hers were in some way independent of her and to be watched and wondered at. At moments it was clearly frustrating for her to require four feet upon which to walk, for she would retrieve a lost marble by clutching it firmly in one hand—usually the right—and hobbling along on her other three limbs.

She was also an adept, if not entirely imperceptible, pickpocket; with impatiently fumbling fingers she would reach disconcertingly into the trouser pockets of any guest who sat down in the house, hardly waiting for an introduction before scattering the spoils and hurrying away with as much as she could carry. With these curious hands she could throw such playthings as were small enough to be enclosed by her fingers. She had three ways of doing this; the most usual was a quick upward flick of the arm and forepart of the body as she held her clenched fist palm downward, but she would also perform a backward flick that tossed the object over her shoulder to land at her other side, and, on occasion, usually when in a sitting position with her back supported, she would throw overarm.

Like Mij, she was an ardent footballer, and would dribble a ball round the room for half an hour at a time. Here she had an additional accomplishment that Mij never learned, for when she shot the ball wide or overran it she would sweep her broad tail round with a powerful scoop to bring it back within range of her feet.

It came as a shock to me to discover that Edal was the most cautious of swimmers. Even in the wild state, otter cubs have little if any instinct for water, and their dam teaches them to swim—against their better judgment, as it were—for they are afraid to be out of their depth. In the water, Edal preferred to keep her feet either in surreptitious contact with the bottom or within easy reach of it, and nothing, at that time, would tempt her into deep water. Within these self-im-
posed limits, however, she was capable of a performance that even Mij might have envied; lying on her back she would begin to spin, if that is the correct word, to revolve upon her own axis, to pirouette in the horizontal plane, like a chicken on a spit that has gone mad. In this, as in the novelty of new "aquatic" powers that she quickly learned, she took a profound delight, and if she had not yet apprehended that otters should swim underwater and only return to the surface for refreshment, she knew all the joys of great disturbance upon it.

By the end of June, she was swimming as an otter should, diving deep to explore dim rock ledges at the edge of the sea tangle, remaining for as much as two minutes underwater, so that often only a thin track of bubbles from the imprisoned air in her fur gave guide as to her whereabouts. (This trail of bubbles I have noticed, appears about six feet behind an otter swimming a fathom or so underwater at normal speed; never, as the eye subconsciously expects, directly above the animal.) But though she lost her fear of depth, she seemed insecure in great spaces of water: I think she needed to see on at least one side of her the limits of the element as she swam, and when beyond this visual contact she seemed seized with a horror vacui, panicking into frenzied dog paddle as she raced for land.

She gradually gained much confidence, however, both in us and in her proper element, and she gambled round us in the warm sunshine as we dragged the boat across the sand into a still, blue sea that reflected the sky without so much as a ripple. We rowed for a mile down the coast line, with the glorious ochers and oranges of tide-bared weed as a foreground to the heather, reddening bracken, and the blue distances of mountain heights. All the magic of Camusfearna was fixed in that morning; the vivid lightning streak of an otter below water; the long, lifting, blue swell of the sea in the sea tangle; the little rivers of froth and crystal that spilled down from the rocks as waves sucked back and bared them.

Edal, finding herself from time to time swimming above an apparently bottomless abyss, would still panic suddenly. She would turn suddenly for the boat, her small face above furiously striking foreflict, cleaving the surface with a frothing arrow of wave, and leap aboard with her skinload of water. Then she would pose herself on the gunwale, webbed hind feet gripping tightly, head submerged, caught between the attraction of submarine exploration and fear of the deep unknown. Sometimes she would slide, soundlessly and almost without ripple, into deep water, only to panic as soon as she had submerged and strike out again frantically for the boat. Yet in the moments when her confidence had not yet deserted her, when the slim torpedo of her form glided deep below the boat's side, weaving over the white sand between softly waving trees of weed, or darting in sudden, swift pursuit of some prey invisible from above, it seemed as if the clock had been set back and it was Mij who followed the dinghy through these shining waters.
Three genera among the living fishes of the world belong to the group known as the Dipnoi—or lungfish—fossil representatives of which are found as long ago as the Devonian period of the Paleozoic era, nearly four hundred million years ago. The higher bony fishes—as distinct from the jawless fishes, the first (and now extinct) jawed fishes, and the sharks—may be divided into two groups: the ray-fins and the lobe-fins. The ray-fins include such common living fishes as herring and perch. The lobe-fins, however, are represented today only by the coelacanth (Latimeria) and the dipnoans.

The three surviving dipnoan representatives are the genus Neoceratodus, found in Australia (Queensland); the genus Lepidosiren, found in tropical South America (the Amazon Basin); and the genus Protopterus, which occupies various African basins. The Order Dipnoi, as the name (dipnoi: "double breathing") indicates, have two modes of respiration: through their gills, in the usual manner of fish, and also through their pulmonary sacs, or lungs, (as do certain other fishes)—for they will come to the surface to gulp air, thus filling their lungs. This allows the lungfish to survive not only in oxygen-poor, stagnant water but even in mud, or away from water altogether. Some ray-finned fishes have similar adaptations, but only a few can leave the water even for short periods.

There is almost no essential difference between the latter type respiration and that of the land vertebrates. It is not surprising, therefore, that these animals were long considered intermediates between the fish and the amphibians. The credit belongs to the Belgian paleontologist Dollo for pointing out over half a century ago that such is not the case. In spite of remarkable convergence, Dollo showed that the Dipnoi did not have been the ancestors of the amphibians, for both morphological and chronological reasons.

Among present-day dipnoans, Ceratodus of Australia has retained the most archaic features. It is only living representative of the family Ceratodontidae; as in its ancestor the skeleton of the paired fins is
One of the four African species of lungfish, *P. aethiopicus*, is seen here in an aquarium setting.
have functional gill filaments. Gill respiration is thus markedly reduced; however oxygen-rich the water in which the animal lives, it must come to the surface regularly for air. Indeed, metabolic studies show that gill respiration accounts for only two per cent of the lungfish's oxygen consumption. *Protopterus* thus absorbs almost all of its oxygen from the atmosphere. As a concomitant, the circulatory apparatus of *Protopterus* is highly specialized, tending toward convergence with the amphibia.

*Protopterus* is generally considered omnivorous, feeding on mollusks, crustaceans, small fish, and frogs. In most cases, however, its digestive tube on examination is found to contain almost nothing but vegetable debris—such as herbaceous plants, leaves, fruits, and so forth—mixed with bottom mud. *Protopterus* is too slow-moving to be much of a hunter: it can, however, snap up any prey that passes within reach.

The lungfish is unbelievably unaffected by even the most serious wounds; its metabolism is probably very low, and its sensory faculties poorly developed. It snaps indiscriminately at everything that passes, and sometimes even devours its own tail. The animals devour each other as well, elder eating younger.

**Professor Bouillon**, of the Free University of Brussels Department of Zoology, has studied lungfishes from the evolutionary point of view in both the laboratory and the field.

*Protopterus annectens* has two distinctive phases. First, there is a burrowing stage, which begins with the dry season. At this time, the animal falls into a state of torpor inside a "cocoons." Second, at the beginning of the rainy season, the animal enters a nest-building, or reproductive stage. At the beginning of the dry season, *P. annectens* burrows down in the bottom mud, hollowing out a shaft, the depth of which varies from a few inches to well over a foot, depending on the size of the animal. For as long as water still lies above the mud, the lungfish makes periodic ascents up this shaft for air.

As the water disappears and the mud becomes progressively drier and harder, *P. annectens* digs in at the bottom of its shaft and curls up. The skin secretes an abundance of mucus, which dries as the mud hardens and soon forms the close-fitting cocoon. On its upper surface this cocoon has an aperture, connected by a tube of mucus to the animal's mouth. The lungfish now enters the torpid state in which it will remain for the duration of the dry season. In order to breathe, the animal slowly and regularly draws in, through the mucus tube, air that travels down the shaft that the lungfish has previously hollowed out in the surrounding mud.

It is important to emphasize that such a torpid phase is a response to the conditions of desiccation in an animal's environment. Torpor does not take place in the ease of fish air to remain in water. In fact, at the very same time that some torpid lungfishes in their cocoons are being dug out of the mud by the natives—who devour them a delicacy—others, in their normal, active state, are being caught by nearby rivers and ponds.

During the course of two field trips to the swamps of the Stanley Pool, near Leopoldville, during 1957 and 1958, Brien, Poll, and the author made studies of another African species, *P. dolloi*. The information that follows is extracted from our joint work, published in the *Annals of the Royal Museum of the Belgian Congo*, *P. dolloi* is found in swamps in the Congo Basin and along the coastal rivers of the French Congo; swamps are its usual habitat.

In the Stanley Pool, different types of swamps can be found: those of the islands of the Bamu Archipelago off the Djiili: the swamps bordering the shores of the Pool; and those at the mouths of the rivers that empty into it. All of these swamps are grassy woods, and access to them is very difficult. Although differing in appearance, they have one characteristic in common. Beneath the surface mat of desiccated mud and vegetation, in the dry season, lies a layer of clear, muddy water, very poor in oxygen.
...rich in organic materials and carbon dioxide. This underlying water zone still communicates with the river, however, and at floodtime water again inundates the swamp.

Most of our observations on P. dolloi took place in the wooded marshes on the shores of the Pool. In such places, it is difficult to walk on foot, because of the tangled mass of lianas, bunches, and fallen tree trunks that have been uprooted and shattered by floods of preceding years. These form a landscape that is tortured and aged, but is also impressive and without grandeur. In the rainy season, when the swamps are flooded, we can catch both male and female P. dolloi. In July, when the waters recede and the swampy ground slowly dries, muddy and wet, the lungfish appear, burying themselves in the soft layer of mud.

P. dolloi thus behaves as does P. annectens when overtaken by the receding of the waters. The latter species, as we have seen, hollows out soil it is drying up, and then wraps itself in a cocoon. In the Stanley Pool, by contrast, when P. dolloi is down into the bottom mud, it encounters a more and more liquid phase, and finally reaches the subterranean water table already mentioned. Normally, P. dolloi enters either a cocoon stage or a state of torpor. It is only in the event of prolonged drought that such behavior patterns are manifested.

Jonnels and Svensson have carefully analyzed the movements with which P. annectens digs down into the mud. They state that the animal hollows out its shaft by forcefully gulping down mud, then ejecting it immediately afterward, through the second gill openings. Adult lungfish, kept in aquarium, have been observed swallowing bottom sand mixed with water. After ejecting it immediately afterward, under force, through their second gill openings—which, as a matter of fact, are their largest. They work to the bottom over in this manner, and make enormous displacements of sand or mud. This, however, is not the method that P. dolloi employs to dig away down into the mud.

Our field experiments showed that P. dolloi buries itself in quite another manner. When placed on top of very soft mud (of the sort that forms the swamp when the floodwaters begin to recede), the animal...
Pea-sized eggs of Protopterus dolloi are a yellowish green in color. These specimens were collected from an entry passage like the one sketched above. Immediately plunged in, headfirst burying itself by body-undulation comparable in speed and character with those of a large earthworm.

Now, normally, as has just been pointed out, P. dolloi undergoes a dormant period. Though it has will drawn to the subterranean water of the swamp, it nonetheless needs to breathe air at the surface. It can do this only by going back up through the top layer of swamp mud. Perhaps to do this, it utilizes the same hole hollowed out in its descent. But more probably it opens up a new path to access to fresh air. In any case, the passage used by the lungfish, as it emerges from the subterranean layer of water, generally has only a slight degree of inclination. When it is foot or so from the surface, the passage turns upward to form a small shaft, open to the fresh air. The shaft exit may be at ground level or, more often, at the top of a little mound of mud, which resembles a molehill. The presence of this mound is clear evidence that P. dolloi digs its channel from bottom to top, forcing the mud outward, mole-fashion. A study of completed shafts further confirms this.
In the dry season, the swamps of the Stanley Pool thus show mounds that look much the same as those in dried-up swamps where *P. anguillius* dwells, but their significance is quite different. Those at the Stanley Pool do not denote the site of a coffin buried in the hardened earth, but rather the terminus of an air shaft led by the active *P. dolloi* in order to breathe air at the surface of the water. The air shaft and its entry channel are hollowed out in the most compact areas of the swamp. The terminal mound is most frequently located among the large roots at the base of some tree stump.

These air shafts in the wooded swamps of the Stanley Pool—and doubtless in the grassy swamps as well—are permanent. They are flood-resistant, lasting until the next dry season, when the same mounds can be seen. The lungfish reoccupy them from year to year, coming back to them at the beginning of the dry season. Since the onset of the dry season varies from year to year, the date

**Young larvae**, collected from an entry passage later in the season, have now grown to stage of mobility. Note that yolk sacs have been partially resorbed.
Scientists' helpers, who deem lungfish a table delicacy, here stab through the hard surface mud near an air shaft with pikes in order to pierce and immobilize the lurking male in the adjacent entry channel. Hunt met with success.

of spawning also varies. The fall of water serves as the stimulus that sets off spawning in animals that have reached sexual maturity.

The number of eggs in a P. dolloi nest is much smaller than the number for either P. annectens or P. aethiopicus. Greenwood reports that the number of eggs per nest for P. aethiopicus varies from 2,000 to 5,000. He further finds that the ovocytes, ready to be spawned in the ovaries of a sexually mature female, number 2,000. This suggests that several females may lay eggs in a single nest. The nests of P. dolloi, however, contain only a few hundred eggs. The ovary of a sexually mature female contains three hundred to four hundred eggs at most. Moreover, while the state of development may vary from one nest to the other, it is homogeneous for each single nest. Thus, it is evident that only one female spawns at each nest.

The spawning of P. dolloi takes place in the entrance passage of the air shaft. The eggs are broadcast along the length of the entry channel, to rest on the bottom mud. This distribution of the eggs can be interpreted in two ways: the female may release her eggs gradually as she moves about in the passage leading to the air shaft; or the eggs may all be expelled at once, and the male may then spread them about as he moves back and forth in the channel.

During the whole spawning period, females with empty ovaries are caught in the river or taken by draining the wettest portions of the swamps. It seems likely, therefore, that when the water begins to recede and the mud is still very soft certain mature females are attracted to the swamp by the males, and then into the entry channel of an air shaft. When the spawning is completed, they are then apparently driven away. Occasionally, if the dry season lasts longer than usual, late-spawning females remain imprisoned in the swamp. They survive only by entering a state of torpor until the next inundation.

It is along the entry channel where the eggs develop and the larvae are born. When these larvae become mobile, however, they congregate in large numbers near the bottom of the air shaft. Only the male remains in the nest, in the entry channel. He is there passively, inactive during the day at least. He moves about from time to time, however, by means of long undulations of the body, coming to the surface of the water at the shaft to breathe. The movement of the male through the channel again helps to dissolve trace oxygen. As the lungfish takes air, a lot of it is expelled, or allowed to escape through the gill openings. These bubbles also contain a little oxygen or permit the formation of air pockets in the channel, where the larvae can breathe. It is thus probable that the male contributes appreciably to the respiration of the larvae.

The male may also defend the young against predatory fish, which inhabit the swamp. It is noteworthy...
at males collected around the nest are large in size, while small males caught in the rivers and tributaries. It would seem, therefore, that cavation of the nest and pairing inuples is the privilege of males that we reached a considerable size.

According to native reports, the ale lungfish is capable of leaving its static redoubt and moving about on a dry surface of the swamp. Most others have repeated this assertion, but we were not able to verify it. We did, however, see captured and wounded males move about relatively rapidly on the ground, propelled by powerful undulations of their bodies.

A moment of inadvertence on the part of a fisherman, we saw one of these males travel in this fashion to a hole from which it had been excised, reach the channel it had inhabited, and make good its escape. It thus not impossible, and perhaps it even probable, that the lungfish moves about on the mud of the swamp, in the manner of eels, at least.
Lungfish larva, above, is anchored
to glass wall of aquarium by its mucus
during the time when the waters are
beginning to recede and the swamp
is still completely muddy.

The abundance of palm fruits in
the gut of nesting males favors this
possibility. The natives report that
when the male (whom they take to be
the mother and call "mama") is dis-
turbed in his channel, he carries off
in his mouth the nestful of young that
he is guarding, in order to save them
from harm. This was the explanation
offered us for nests found suddenly
emptied following our first collection
of young. No rigorous observation
was made that would permit us to con-
firm the native claim. However, we
caught one male at the nest with
eggs and hatched young in its mouth
and gill cavity; another was caught
with its gut stuffed full of larvae. It
must therefore be conceded that the
male is capable of taking eggs and
young in its mouth. But perhaps it
does this involuntarily, as is the case
with everything it ingests, by breath-
ing in water under force, ready to
ject the swallowed objects through
the gill openings, as is its habit.

As soon as the larvae can move
about, they gather in schools in
the channel near the air shaft, for
even in this early stage it is urgently
necessary for them to come to the sur-
face of the water to breathe. Three
modes of respiration thus succeed one
another during the period of lungfish
larval growth. As the embryo de-
velops, respiration through the outer
cell layer is reduced and external gills
develop and take over the function of
respiration. The lungs, however, are
also developing at this stage and soon
become the essential organs for the
exchange of gases. Later, the internal
gills will appear; these are markedly
reduced in size. As noted above, aero-
lial respiration is essential to the Dip-
noi. Coming regularly to the surface
of the shaft to breathe, the larvae will
there await the rising of the waters
that inundate the swamp and frees
them in the rainy season. Having ter-
minated their metamorphosis, during
which the external gills disappear,
they are able to move about and feed
on small organisms living on the sur-
face of the mud or among the roots
of grasses and papyrus.

In the swamps of the Stanley Pool,
as we have seen, the lowest level re-
mains saturated with underground
water that normally extends to the
river. After spawning, the females can
return to open waters by this route.
The males remain near the larvae in
the channel, which leads to the air
shaft, awaiting the rising of the wa-
ters. However, when the dry season is
exceptionally early, long, and very
severe, males may be trapped in their
channels, from which the water pro-
gressively disappears.

What becomes of these lungfish
when they are immobilized in a
swamp undergoing pronounced desic-
cation? Are they capable of entering
a state of torpor to await the coming
inundation, which will free them?
We tested this with an experiment.
Two large barrels were filled two-
thirds full of very soft mud, with
a thin layer of water on the top. Two
P. dolloi, which had been caught in
the river, were placed on top of the
mud, one in each barrel. They imme-
diately buried themselves. After two
months, the thoroughly dried mud
was carefully removed. In each bar-
rel, the lungfish was found to be in
state of torpor. When these two spec-
mens were placed in water, they im-
mediately regurgitated large bubbles
of gas and, little by little, resumed
normal activity. From this experi-
ment it may be concluded that P. dolloi
when conditions demand it, may re-
main buried in a state of torpor. In
this state it awaits the next flood wa-
ters that will permit it to resume its
normal, aquatic life.

It may therefore be concluded that
P. dolloi is capable of entering a
state of torpor when overtaken by
desiccation of the swamps; behavior
that is known to be normal in the d
season for the other three species
this genus. When the water agar
rises, the latter three species awake
leave their cocoons and enter an act
ive phase that includes sexual repro-
duction. But the fourth—P. dolloi
the Stanley Pool—buries itself in the
mud not to enter a state of torpor, b

At the start of this article, it was
pointed out that the Dipnoi could n
be the ancestors of the land verti
brates. If present-day Dipnoi sh
numerous similarities in developme
and organization with the amphili
ans, these similarities are attribu
ble, in part, to common ancestry
however remote, and in part to co
vergent characteristics associated w
a somewhat similar way of life. T
Dipnoi, as well as those lobe-fini
dishes that gave rise to the amphi
and, probably arose from a com
ancestral stock at the beginning of t
Devonian period or perhaps som
what earlier. These two groups
fishes, however, evolved toward to
restrial life with unequal success. T
swim bladders of ray-finned fish, t
branchial sacs of Dipnoi, and t
lungs of land vertebrates stem fr
single organ; the pulmonary air bl
on of the earliest higher bony fish
The remarkable adaptability to e
vironment exhibited by the lived

Older fry, right, exhibit growth
feeler-like fins. External gills van
when the metamorphosis is comple

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NATURE and the MICROSCOPE
Some insect adaptations

By Julian D. Corrington

Directions for preparing permanently mounted microscope slides of entire insects and such of their parts as antennae, wings, and legs were given in our previous installment [Natural History, May, 1960]. What is the value of work of this nature, aside from providing a new tool for the microscopist? Many readers will find much interest and instruction in forming a collection of slides of antennae or of insect legs; but their interest will rise proportionately as they do something with these mounts, after they are dry and ready to inspect.

There is one type of collector who assembles as many of a particular class of objects as possible—he be stamps, coins, shells, or spread butterflies—and who revels in mere numbers, always seeking the new specimen. The serious collector will, however, as his acquisitions grow, begin to study and to classify them. Stamps tell a story of geography, history, biography; natural objects, when arranged systematically, reveal evolutionary sequences and provide marvelous instances of origin and phylogeny, as in rocks and minerals, or of adaptation (the adjustment of the organism to its environment) as in fishes or insect legs. Structural study is fascinating, but it is of little value unless it is correlated with observations of the function of the various parts. Let us see how these principles can be applied to the collection and study of a set of slides of insect parts.

Among members of the great Phylum Arthropoda, the largest by far of all animal groups, the number of antennae provides a major feature in classification. Crustacea, like the crayfish, have two pairs; insects, centipedes, and millipedes have one pair each; spiders and their allies have none. All adult insects have one pair, though they are sometimes minute, as in the flea or dragonfly, or rudimentary in the procutans, where they are termed pseudoculi (false eyes), the first pair of legs functioning as antennae. Known also as feelers or "horns," antennae are movable and segmented appendages of the head that rise from in front of or between the eyes, or from the sides of the face, and fit into sockets. They are primarily tactile organs, bearing hairs and spines that are highly sensitive to touch stimuli. They also include the organs of smell, and often of taste and hearing. Hence, for information about their environment, insects depend to a high degree upon their antennae.

As can be expected in the case of an organ of such functional importance, the antenna has undergone a remarkable series of evolutionary changes in the different orders of insects. As each order went through a divergent series of modifications of all its structures, the antennal pattern changed by natural selection of that type best suited to the environmental conditions of the particular kind of insect.

Entomologists recognize some thirteen forms of antennae. The setaceous or setiform (seta, bristle) antenna is slender and tapering, each segment slightly smaller in diameter than the one preceding. Look for these in certain species of ground beetles, blister beetles, long-horned beetles, moths, flies, and cicadas. Much commoner is the filiform (filum thread) antenna, with all the segment of about the same diameter. This type is long and slender, and occurs on such tiger beetles, diving beetles, long-horned beetles, kissing bugs, moths, wasps, grasshoppers, crickets, and roaches.

In a modification of the filiform design, each segment is globular in shape so that the antenna resembles a series of beads on a string. This is the moniliform (monile, necklace) type, found in many weevils, March flies, darkling beetle, and pinnate beetles. The next variation is the serrate (serra, saw) antenna, of which the lateral surfaces have spines or toothlike extensions, giving a saw-tooth effect to the whole appendage. Insect with serrate antennae include some of the click beetles, metallic wood-boring beetles (Buprestis), death watch beetles, and some crane flies.

A further lateral extension of the serrate pattern produced the pectinate (pecten, comb) antenna, which resembles the ordinary hair comb along the outer surface, or sometimes on both surfaces (bipectinate). Some of the click beetles illustrate this design, which is also found in goat moths, tiger moth and the males of noctuid, puss, tussock and some sphinx moths, and in some of the crane flies. Females of the giant silk worm moths, a group that includes the huge and showy species—the Io, Atlas, Promethea, Cecropia, Polyphemus, and Luna—known to all collectors, has bipectinate antennae. The plumo-
plumula, feather) antenna is the final outcome of this pectinate trend, the processes being long, fine, and numerous, as in the males of the giant silkworm moths. The Habellate (habellatum, fan) variety is another modification of the pectinate antenna, with very long extensions that together present a fanlike appearance. This type occurs in the weevils, an order related to beetles, which are mainly parasitic in other insects, notably in bees. **W**horted antennae are basically one of the simpler types (setiform, filiform, moniliform), but with whorls of hairs around each segment, as in sand flies and mosquitoes. A different kind of modification has the terminal portion of the antenna enlarged, rather than tapering. If the segments increase in diameter in passing toward the apex, the structure is termed **ante** (elava, club), and a large number of insects have clubbed antennae, including many of the Hymenoptera, sterc-scavenger beetles, staphylinid beetles, dermestid beetles, carabid beetles, **hy**brid beetles, some tenebrionid beetles, some death watch beetles, chrysomelid beetles, bean weevils, butterflies, inch bugs, lace bugs, and ambush bugs, modified clavate design is the **capitate** (aput, head), in which the enlargement segments occur abruptly and only at the tip, forming a knob. The skippers, group intermediate between moths and butterflies, have capitate antennae with recurved hook at the end of the knob. Some bark beetles and members of the asp-bee groups exhibit this type.

A specialization of the capitate form is the **lamella** (lamella, layer) antenna, which is so marvelously displayed in scarabaeid or dung beetles. The apical knob is divided into plate-like or flake segments that can be folded tightly together or expanded into separate leaves. It is interesting to observe these beetles opening and closing the plates of one of its antennae. The elbowed or **genulate** (gena, see) type, in which the antenna is bent more or less of a right angle, is characteristic of ants and many other Hymenoptera, of weevils, and other insects. A final form is the aristate (arista, awn), an elaboration of the capitate antenna. This occurs in the higher Diptera and consists of an enlarged apical segment, which bears a single or a segmented spike-like side piece, the arista. The house-fly, with a plumose arista, provides a good example for mounting.

A set of slides of whole mounts of these antennal types provides a series of progressive changes. They start with the simple setiform and filiform feelers, advance through one tendency to lateral projections (setiform, pectinate, filiform, plumose), or through another trend toward specialization of the apical end (clavate, capitate, lamellate, aristate). The final development is the elbowed or geniculate pattern, which may also be clavate, filiform, or some other type beyond the bend of the elbow. These antennal patterns do not follow any taxonomic sequence that makes them ordinal characteristics of insects; that is, all Lepidoptera do not have capitate antennae, or all Coleoptera pectinate antennae. Within each of the major orders of insects, antennal evolution has followed its separate pathways. This means that a geniculate antenna in a weevil is not phylogenetically related to a geniculate antenna in an ant, for the weevils are an end line of evolution among beetles, and the ant is an end line among the Hymenoptera. The two forms of geniculate antennae differ in detail while conforming to a generalized pattern. This is a case of convergence, wherein structures or habits of diverse heredity in unrelated organisms come to an apparent similarity because of similar environmental requirements.

The mouth parts and wings of insects offer many opportunities for comparative study, but we shall close this chapter on entomology with some remarks about the legs of insects. These are always six in number in adult insects—

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three pairs. Hence, one of the synonyms for the Class Insecta is Hexapoda (six legs). For the most part, the legs are similar in all orders, but they display remarkable adaptations for various modes of life. There are five parts of an insect leg: coxa, trochanter, femur, tibia, tarsus. The coxa is that chitinous segment that is so set into the body that it acts as a ball-and-socket joint for the whole leg, with the coxa as the ball. The trochanter is usually a short segment, but may be elongated in dragonflies and earabid beetles. The first major segment is the femur, named from the thigh bone of man. This is the prominent and thick division of the grasshopper leg, containing powerful muscles for leaping. Then comes the tibia, generally the longest segment, highly modified for a great variety of uses. It was named from a fancied analogy to the chief bone of the human shank. Lastly, there is the tarsus (in man, the ankle), a single segment in primitive insects, but with as many as five divisions in the more highly specialized orders. If the first tarsal segment is much enlarged, as in the honeybee, it is termed the metatarsus. One or two claws terminate the leg and there may be one or a pair of pulvilli—padlike cushions. These are located with or between the claws, allowing the insect to cling to surfaces, and are used, for example, by the fly walking across the ceiling.

The primary development of the insect leg, as with other great groups of animals, is ambulatory, and the construction is correspondingly simple and generalized. All of the five segments are in proper proportion, and none is specialized for other than ordinary duties. Most of the segments are fairly short; those of the wasp are a good example. Elongation of parts results in the running or cursorial leg, specialized for speed on the ground, as that of the roach or tiger beetle. The fossorial leg is adapted for digging, and the first leg of the mole cricket with its weirdly shovel-like extensions, is the classic example. The natatorial leg, such as the third one of the diving beetle, is specialized for swimming—flattened, elongated, and fringed with hairs to make an oar. The saltatorial leg, greatly enlarged and extra powerful, is for jumping. The hind legs of the grasshopper or flea are examples. The scissorial leg is the climbing leg. This is exemplified by the third leg of the grasshopper. Its spikes enable this insect to climb up grass stalks in the same manner as the telephone lineman climbs up a pole.

Among non-locomotor specializations of the leg is the raptorial type, such as in the foreleg of the praying mantis. Here the femur and tibia are armed with formidable spines, and when these two segments close upon one another the spike are driven through the body of a hapless victim and hold it securely while the mantis dines. This fiendish and highly efficient device recalls the Iron Maiden infamous machine of days of the Inquisition. The stridulatory leg is a sound producing mechanism. In certain of the Locustidae the hind femur is armed will a series of minute pegs that are rubbed against the edge of the first pair of wing to set up a vibration with which all of us are familiar. The scraper of this musical instrument shows up very well in a slide mount. Another case of special interest to those who make slide preparations is that of the larva or grub of the Horn Passalus, a wood-boring beetle. The cox of the middle leg bears a file, a series of very fine ridges, against which the dwarf third leg is rubbed as a scraper. This leg is so small that until the insect is inspected closely it appears to have but two pairs of legs.

Having examined the structure of number of types of insect legs, the next step is to watch them in action. Place diving beetle in an aquarium and note how he swims; watch a grass-hopper climb up a stalk of grass in a meadow offer a mantis a fly or small grasshopper and observe how he uses his forelegs.

Of all insect legs, however, the most ingeniously adapted for a variety of performances are the three types of the worker honeybee. The spectator stand close to a bee in the field and see these legs in action, or he may perhaps have access to a glass hive, such as are installed in many schools and museums and penetrate the secrets of the hive a well as those of bee anatomy.

When we put the microscope to work on the finer details of insect leg construction, we shall find need for some additional terms. Proximal indicates nearness to source; a location nearer the center of the body than that of some other structures. Thus, the coxa is the proximal segment of the leg; the metatarsus is the proximal division of the tarsus. Distal indicates the opposite relation—distant. The tarsus is the distal division of the leg.
movable, but it cannot close over the notch by itself, as it has no muscles of its own; the closure of velum over notch is effected by closure of the leg joint, with the metatarsus flexing on the tibia. It is sometimes said that the antenna is drawn through the cleaner, whereas the opposite motion plays the major role—the flexed leg is drawn along the antenna.

The mesothoracic leg, being in the middle, is the least modified of the three.

There is a pollen brush on the flattened metatarsus, similar to that on the first leg, and it is used to remove pollen from the forelegs and adjacent body parts. Projecting from the distal end, or inner face, of the tibia, in a location corresponding to that of the velum of the first leg, is a spur, the most controversial of bee leg structures. Some scientists call it the "pollen spur," and describe it as an organ for digging or prying the pollen balls loose from the baskets (soon to be described) when the bee fills a cell of the comb in the hive. Others have said that the spur supports the wings as they are being cleared by the nearby pollen brush of the metatarsus. Still others refer to it as a "wax pick," and say the spur removes the plates or scales of wax from the wax packets on the underside of the abdomen, where this comb-making material is secreted. Possibly all of these observations are correct, and the spur is, in fact, a multipurpose implement that performs each task at a different time.

Largest and most complex of the bee's appendages is the metathoracic leg. As on the other legs, this carries a pollen brush, located on the outer face of the metatarsus, and used in clearing pollen from the rear portions of the body. In addition, this leg carries a pollen basket, pollen packer, and pollen comb. The pollen basket is a most conspicuous and amazing sight when filled, and a deep-well or high-ringed slide may be prepared to show this condition. It takes up most of the outer surface of the tibia, which is not only concave, but also is bordered with incurving, stiffened hairs that assist in supporting the ball of wet and sticky pollen that is carried back to the hive. The basket enables the worker bee to spend more time in the field and make fewer and longer trips than would be the case without a specialized pollen-transferring device. Its Latin name is cohaedris, or "little basket."

At the distal end of the inner edge of the tibia lies the petro, a comb of short, spine-like hairs, opposite which—at the proximal end of the metatarsus—is a projecting, rounded, smooth lip or plate called the auricle. Preten and auricle constitute the pollen packer. Formerly they were termed the "wax pinner" or "wax sheath" and the mistaken notion that they removed wax from the wax pockets. Lastly, on the inner surface of
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the metatarsus lie some ten rows of stiff, distally pointed spines, the pollen comb.

Those who find these adaptations interesting may wish to see them for themselves. Slides are easily prepared. Remove the three legs from one side of a freshly killed worker honeybee, and the third leg, from the same side of the body, from a second specimen. Each leg may be placed on a separate slide, but we prefer a composite mount, with all four on a single slide: prothoracic leg, outer surface toward the viewer, at the left; mesothoracic leg, outer surface; metathoracic leg, outer surface, then metathoracic leg, inner surface, the last leg duplicated so that both pollen comb and pollen basket can be seen.

In removing these appendages, be sure to get them complete, including the coxa. Then pondash in 10 percent potassium hydroxide until the legs are a medium golden-brown color, wash them thoroughly in water—preferably a gentle trickle of running water—dehydrate them, clear, and mount them, paying special attention to positioning. When dry, the slide may be studied or photographed. Then, "go to the bee, thou sluggard," and observe closely how she employs these intriguing structures, using a reading glass, if possible.

The bee gradually becomes covered with pollen. She then brushes the grains from the fore parts of the body with the pollen brushes of the first pair of legs and these grains are mixed with others that have been gathered by the mandibles and made sticky with regurgitated honey. This load is now taken by the pollen brushes of the second legs, and finally by the pollen combs of the hind legs, the left comb receiving the contributions from the side right of the body, the right comb serving the left side.

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Now the pecten of each metatarsus scrapples the pollen from the comb of the opposite leg, alternately, and at a bit of a time. The increments are loosened, the tarsus is flexed, and the pollen is packed by the auricle into the lower end of a pollen basket. Each addition adheres to the preceding mass, causing the ball of pollen to grow until it is very large. Meanwhile, the bee may also be employed in cleaning its eyes, mouth, and other parts. At the hive, the worker arches over a cell of the comb and uses the spurs to pry the pollen masses loose.

The drone and the queen do not have these pollen-gathering and carrying structures. It is curious, therefore, to see the size and shape of the greatly enlarged leg segments are approximately the same in these casts as in the worker bees: the tibia and metatarsus of a hind leg in all three casts are large, wide, and flat, but only the worker has the pecten, auricle, comb, and basket. All of which points up the biological definition of a bee. To the poet the worker bee is the symbol of industry; to the student of government and sociology she is the perfect example of co-operation without friction; to the farmer she is an important economic asset, producing honey and wax of great value; but the biologist the bee is, par excellence, "a bundle of adaptations."

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Sebastodes serriceps, adds color

Corona del Mar. California. This species

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fauna as white barnacles, often nests in calm water near the base of siltstle
reefs, a locale it shares with sea urchins, with which it is always associated. 1 s
photo and other excellent examples of submarine photography were made by
Willis E. Pequegnat while studying the life in coastal waters from just below
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it, this Scuba Zone is examined in Dr. Pequegnat's article, which starts on pag
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DAY last January, the American Museum's youngest Life Members—Pamela Golden, age six, and her sister, age seven—dropped in to say hello. On the following day, Winifred Kirkland, one of our oldest Members, by for lunch. The Golden girls have just become Life members; Dr. Kirkland has been interested in the Museum over eighty years—ever since a visit with her parents to our first temporary location in the old Arsenal building on the east side of Central Park.

In two young Life Members made a charming picture as they came into the Members' Room, wearing identical green-patterned dirndls, white aprons bordered with gray wool knee socks, and black shoes. They wore dark brown hair in Dutch bobs, sat very straight in the chairs, and giggled in un-Life-Memberish fashion.

They said that they go to The Brearley School and are using reading, writing, phonics, science, rhythm, and work. Pamela said she has made a wooden bed for a Christmas doll. She and her sister may be the only Life Members who still play with dolls.

though they have been to the Museum only four times. Sylly and Pamela have their favorite exhibits, and their preferences are the Hall of North American Forests and the little live exhibit in the Natural Science Center. Neither has strong opinions about what they hope the Museum will be doing in the future, but if they match Dr. Kirkland's attachment to the institution, they will have been many years ahead of us when we know their views.

Kirkland is petite and snowy-haired, with bright blue eyes that sell do not need the aid of glasses. She remembers her first permanent Museum unit when it stood alone off Sixty-Seventh Street. When the second unit was opened, she walked up the stairs (now closed) on either side of the Seventy-Seventh Street archway to enter the focus, and she wishes she could do it again. For such longtime Members, this doubtless could be arranged.

A child, Dr. Kirkland had to empty her pockets of coins and other attractive objects before her parents permit her in the house. She conducted some youthful experiments: finding out for herself that milk snakes do not milk cows, that “glass snakes” cannot join their divided bodies, and that snakes will die before sundown if properly scotched. She wound up with a Ph.D. in anthropology from the University of North Carolina, living with the Havasupai and Hopi Indians as part of her work. In 1949, F. Trubee Davison, then President of the Museum, made Dr. Kirkland a Fellow, in recognition of her work for the Contributors' Program (which raises funds to support the Museum's scientific and educational work).

Dr. Kirkland has noted, for the better part of a century, the Museum's growth in the fields of research, education, and exhibition. She has one fetish about us—that we should save money wherever possible in order to accumulate additional funds for our programs. She suggests, in a twinkling way, that since the Museum gives so much for what it receives, we'd have more money for the things we want to do if we were, perhaps, not so generous.

The Museum, of course, does give much for what it receives. Conversely, the more it receives, the more it is able to give both to its Members and to the general public.

We are, at this moment, working to complete the recently opened Hall of the Biology of Man. In the Hall of Indians of the Northwest Coast, we are restoring the murals, cleaning the collection, and improving the lighting. A few of our future plans include a new Hall of Human Behavior, and a Hall of Civilization, and reinstallation of the Hall of North American Birds, and the exhibits concerning the Eastern Woodlands and Plains Indians.

To do all these things, of course, requires money. Present Membership dues make up a valuable and important part of the Museum's operating budget, and we appreciate the support of our entire Membership. But to do what must be done, we must ask for even more—outright gifts, bequests, and an increase in Members' support through enrollment in higher categories.

There are two extremes represented in the respective Life Membership of the Golden girls and Dr. Kirkland—the first two just beginning what we know will be a long and pleasant association with the Museum; the second continuing her more than four score years of devotion to a scientific ideal. Somewhere in between these two extremes stand almost a hundred thousand Members who can take an even greater part in the present and future work of the American Museum. We ask for your encouragement.

William A. Burns
Membership Chairman
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The Fortunate Island

Journey into Summer. by Edwin Way Teale, Dodd, Mead, $5.95; 366 pp., illus.

A n archetypical ritual of American culture is packing the family car for a trip. Into the trunk or on the rear deck go the bags and the Coca-Cola cooler, the sunburn cream and the transistor radio, maps, bottle warmers, and all the impedimenta of the well-equipped, part-time nomad. Three times in the last ten years or so Edwin Way Teale and his family have followed this familiar pattern—with a difference. The important baggage that the Teales have carried has been notebooks and field guides, cameras and film and, most important of all, an encyclopedic background of nature lore.

Out of these trips Teale has fashioned three of the most popular nature books of this century—North With the Spring, Autumn Across America and, most recently, Journey Into Summer. The form of each volume is the record of a naturalist’s travels in the United States during a single season. But these are no casual Touristian jaunts—to “Week Along the Concord and Merrimac.”

The planning and logistics of each highly organized ramble are at once the main strength and one weakness in Teale’s approach to nature. He brings to his travels half a lifetime of nature study, the eye of a professional photographer and magnificent staff work. For his intention is not to immerse himself in the experience of summer or autumn or winter; he intends—and to a large measure succeeds—to surround it, overwhelm it, capture it definitively in a hundred notebooks and rolls of film.

The campaigns—the military analogy is inevitable—are carefully conceived, the product of painstaking, intelligent staff work. Unlike the careless, casual traveler, Teale knows that a fog of mayflies will hatch from the mud of Lake Erie between May 17 and June 23, and plans his trip accordingly. He is confident of encountering a dust storm in northern Nebraska in August, and arranges his itinerary to ensure the rendezvous. Almost every one of Journey Into Summer’s thirty-four chapters is built round one or another such confrontation—all three-starred in a naturalist’s Bae-deker and all, perhaps, a little pointing to a reader for being inevitable. The effect is faintly flat, an oversophisticated dinner menu.

Read connectedly as a narrative, Journey Into Summer, and its predecessors, suffer badly from this type of organization. Indeed, they are close to unreadable. But, by an oddity, the same meticulousness and careful distillation of long hours of library research, of personal observation and experience, make all of the volumes extraordinarily effective on quite another level. Much of the charm of nature book traces back to two human delights—the wonder of strangersness and delight in simple diversity. A former human taste is what makes bestiary, the traveler’s tale, and fairy story eternal favorites. The accounts for the continuing fascination of the catalogue—from Rabelais to Roehm, and even the World Almanac.

As such compendia—as modern highly scientific successors to the prevail ing books of wonders—the Teales are endlessly informative and diverting to the browser. Their value is increased by the author’s determination, reminiscent of the monkish copyist annotator, to let no stray fragment of lore or parenthetical bit of byplay escape him. Thus, in recounting a visit to the fabulous fossil-shipshakes of Florissant, Colorado, a manager to include tabloid biography of two eminent entomologists and to relate the history of the unhappy amateur Berenger—systematically duped by students who progressed in carven his fossil herbs and algae producing fossil astronomical ob and finally, after he had published finds, his own name in fossil form.

The author also has an enduring statistics. Almost every page is perched with the kind of numerical that has durable, extrinsic fascination; however trivial its intrinsic import: 12,000 osage orange seeds weigh than a pound (and are food only.
A man may a million leaves; Niagara Falls (virbly) is over 150 feet high, flows at the rate of 200,000 cubic feet a second, and is lit at night by 20 colored lights with a combined strength of 2 million candlepower. Fireflies, on the other hand, never manage to emit more than 1/500th candlepower and may dim as 1/16,000th.

1 and fox squirrels; an elm may a million leaves; Niagara Falls (virbly) is over 150 feet high, flows at the rate of 200,000 cubic feet a second, and is lit at night by 20 colored lights with a combined strength of 2 million candlepower. Fireflies, on the other hand, never manage to emit more than 1/500th candlepower and may dim as 1/16,000th.

With all its enticing sides and sumptuous garnish of facts, the greatest weight of Journey Into Summer lies in xen, sharply reported capsule essays.

These essays are headed along the line 19,000-mile string of the Teales' renderings like the shiny stones of a place. The subject may be anything in the history of grasshoppers whine to the tops of glaciers—frozen-in, eventually disgraced at the melting of the ice to provide a feast for a generation of birds—to the unexceded mystery of the birdeye maple strange, mottled grain is characteristic of a species or a special kind, but a growth aberration of initial seed. Suga maples, not rooted in surrounding trees and often arising during the life of the individual, again in a page or two, Teale the invasion of the Great Lakes laments by the digging of the land Canal bypassing the Niagara, its disastrous effect on the fishing industry, and the long and ultimately fruitless search for a method of eliminating the eel-like predators.

Voices of the many worlds of nature Teale passes by in his travels is too little for consideration. He pauses in a vast wheatfield to review the tiny, eeking world of the field mice—laid bare and wasted by the catastrophic time of harvest. In Oklahoma, he adds, that drought-proof resident of the soil, the box turtle—which has been known to jump in order to catch shoppers and, though it hates water, calmly to dunk first one end of its body and then the other in a pool to rid all of annoying ants. He recalls that Samuel Lewis, of expedition fame, assured the leap of a prairie jack rabbit twenty-feet and remarked that years are very flexible, the animal uses them with great ease and quickness and can contact and foist them on back or delete them at pleasure: "The old man's" years are constantly "dead" for such pleasant echoes from the far and, like all good travelers, he enters his own experience whenever he has contact with the words of those who have sealed the road before him.

Armstrong, some of the sharpest portrayals in Journey Into Summer is in the field of history. Teale tells again two stories that can never be told often enough: one of the pursuit of the passenger pigeon by market hunters, who sometimes used decoy pigeons with their eyes sewed shut. In half a century, they reduced the species from flights of two billion birds to a single specimen that, dying in a zoo in 1914, brought to completion the extinction of its race. The other tale relates the near-extinction of the bison—an action even more senseless than the killing of the passenger pigeon, since much of the slaughter was done in the name of sport. The British nobleman who moved into the West in the 1850's with a rajah's retinue and, in a single hunt, left 2,500 buffalo carcases to rot along the banks of the Yellowstone, beseech. As Teale says, "like a bloodthirsty wasp in a henyard." But perhaps he was little worse than the hide and tongue hunters who left such a trail of bleached bones across the prairie that in later years they could be stacked ten feet high in half-mile piles along the railroads for shipment to eastern fertilizer factories. Happily not all the stories of men and nature are quite so melancholy. One of the Teales' pleasant memories is of the amiable symbiosis of tourists and bears around the town garbage dumps of northern Michigan, where bears feed—and tourists watch them—with mutual dignity and respect.

Readers of North with the Spring and Autumn Across America will have recognized that Journey Into Summer is cut to precisely the same pattern—in this case, a recommendation. The itineraries are different and each season has its own wonders, but actually the three books so far published—and the volume on winter yet to come—are a single work, one huge miscellany appropriate to the size and splendid variety of the country it celebrates. Celebration is the proper word, for Teale loves his country in perhaps the deepest way of all, with a passion that embraces rocks, soil, streams and air, and every living inhabitant.

In the face of so much to admire in an undertaking of the scope of Teale's books of the Seasons, it is perhaps ungrateful to criticize one aspect of the first three volumes that is uniformly unsatisfying. Teale is a nature photographer of the old school, straightforwardly and technically more than competent. But his anonymous picture editor is incriminately literal-minded. At their best, the photos his editor selects are pretty or cute; often they miss even this limited distinction. Almost nowhere are they the wonderful, awe-inspiring, beautiful, nostalgic, or simply detailed and informative pictures Teale knows so well how to take. These island selections—there is always one showing the author, surrounded by nature and hard at work enjoying his surroundings—are in no way worthy of the subjects or the text they purport to illustrate.
IN BRIEF  By John Hay

A History of Polar Exploration, by L. P. Kirwan, W. W. Norton and Co., $5.95; 374 pp., illus.

The story of polar exploration is one of trial, tragedy, and success on a major scale over many centuries, from the time of the Vikings to the explorers of the International Geophysical Year. Its history necessarily comprises a wide range of men and nations. The author, who is the Director of the Royal Geographic Society, has managed to assimilate the available material and has used it to write an excellent history book, the first to cover polar exploration in both the Arctic and Antarctic.

The various episodes, which combine to make up the great theme, are concisely presented. Clearly written and often exciting to read, Kirwan's history will doubtless be a definitive work on the subject for some time to come.

A Walk in the Mountains, by Ralph and Molly Izzard, David McKay Co., $4.95, 253 pp., illus.

A British foreign correspondent and his wife, Ralph and Molly Izzard, bought three donkeys, took their four children and a Lebanese friend along, and set off on a trip through the wildest parts of Lebanon. Their account of the journey makes very agreeable reading. It is written with modesty and good humor, and at the same time manages to give the reader a sense of the country and the life of its people.

Digging Up America, by Frank Hibben, Hill and Wang, $5.00; 239 pp., illus.

The general reader's need for a compact account of archeological efforts in the Americas, and the results to date, will be completely filled by Digging Up America, written by a professor of anthropology at the University of Mexico. To learn more about the Aztecs, Mayans, the Mound Builders of South and Midwest, Pueblo Indians, and Eskimos, the reader, if he is so minded, will be obliged to go much deeper on his own; but Digging Up America provides a good introduction to the field.

Spindrift, by John J. Rowlands, No. $3.95; 232 pp., illus.

Spindrift is an easygoing book of incisence and description, and also full of the healthy spirits of a man who has retired and uses his retirement to good purpose. John Rowlands watches the tides, gulls, flowers, or ships near the seacoast house in Massachusetts that are the same alert interest and welcomes gives to his small grandson. Rowlands is a sensitive and balanced writer wh...
to share his pleasures and excursions with the reader. The fact that the book was written, as its author admits, "randomly" and "in no particular order" does not diminish its merits.

**Children of Li'lith, by Guy Piazzi Dutton, $5.95; 200 pp., illus.**

Guy Piazzi was the leader of an ethnographic expedition to Borneo. He lived primarily in the Dyaks and more remote forest neighbors, the Hans; societies that are seriously endangered by the encroachments of civilization. His account is a short one and, translated from the French, written in a somewhat artificial style. The reader is greatly tempted to ask for more than he gets in this book, but it describes two threatened primitive societies with sympathy.

**On the Wilderness, by W. Douglas Burden, Atlantic-Little Brown, $6.00; 351 pp., illus.**

The wilderness world and the wilderness-life that Douglas Burden writes about, as an adventuring man who knows what he speaks, is unfamiliar to most of us, for the wilderness is disappearing as a great part of the habitable globe. This book records a lifetime of travel hunting in Alaska, Nicaragua, Indonesia, Mongolia, and the East Indies. Burden is one of those "big game" hunters and collectors who does not fret about his occupation. "It is a desolate thing," he writes, "to love wild animals and yet to kill them." His writing is early in the book, especially as it includes his young manhood in the wilds of Canada and Alaska, is haunted by the aliveness of nature and reveals sensitivity to its beauty.

**Sverdrup's Arctic Adventures, adapted by T. C. Fairley, Longmans, $6.00; 305 pp., illus.**

Although adapted by T. C. Fairley, Sverdrup's Arctic Adventures is really a reissue of the Norwegian explorer's own work: New Land: Four Years in the Arctic Region. Sverdrup is a strong, self-reliant man, an accomplished navigator, who had his apprenticeship in exploration under Fridtjof Nansen. His continuous voyages and his journeys in the Canadian Arctic between 1895 and 1902 were of great importance in the charting and understanding of that area. His story, somewhat episodically told, which is consistent with the many separate expeditions involved—is still fresh and vital. Sverdrup's observations on natural history are original, humane, and interesting.

The impression that comes through to the contemporary reader is one of an indefatigable explorer, and a courageous one, at the same time, modest man.

**The Wonders I See, by John K. Terres, Lippincott, $5.00; 256 pp., illus.**

From many years editor of Audubon Magazine, Mr. Terres here reports the results of his lifetime of detective work in nature, and his enjoyment of his work. The author, who was also in the Soil Conservation Service at one time, is one of those rare human beings who is trained in looking round him and analyzing what he sees. The book is divided by chapter headings into the twelve months and each month's passage brings up many thoughts, observations, and stories in the field of natural history. Can snakes hear? Do gray squirrels find their winter food supplies by memory or sense of smell? Where do birds sleep at night? Did you ever watch the birth of a gall wasp? Have you ever heard the story of the "Great Lapland Longspur Tragedy?" This "naturalist's notebook" is varied and unfailing interesting.

**The White Spider, by Heinrich Herrer, Dutton; $6.95; 240 pp., illus.**

This book on mountain climbing is unusual not for the writing, which is harsh and inflexible, but for the nature of the subject. The North Face of the Eiger, in the Bernese Alps, is a formidable, sheer wall of icy rock, six thousand feet high, that has claimed many lives. Although it has been climbed successfully it has continued to take its toll over many years, and those who were tempted by it were not infrequently criticized for recklessness. Heinrich Herrero, one of the successful climbers, comes to these mountaineers' rescue with an account of the many attempts made and the terrible risks involved. One supposes there is little room for humor in such an enterprise, but that is just the element we miss most in this stiff, defensive book—not unlike the North Face itself.

**Diving for Pleasure and Treasure, by Clay Blair, Jr. World Publishing Co., $4.95; 340 pp., illus.**

This book's trivial title belies an account of underwater exploration that is of some historical interest. The author and an indefatigable ex-marine, a diver by the name of Bob Marx, were first associated during an inconclusive search for the famous Civil War ironclad ship, the Monitor, and they later joined in an expedition to explore a 200-year-old wreck off Yucatan. They became involved in enough accidents, government incidents, rumors, successes, and failures to attract any boy or frustrated adult adventurer who reads this book. But this is also good reading for anyone with a historical bent, since it culminates in some intriguing re-search into Spanish and English colonial trade in the New World—all in all, amateur, but fun.
WHEREVER COASTAL ROCKS RUN into the sea or marine rocks rise in isolation from the ocean bottom to form miniature mountain ranges, one can be sure that many unsuspected marine animals await discovery. It can be predicted that some of these animals will be completely new to science, whereas others will be species that, although well known from other locales, have never been observed in the particular area being studied. I am moved to assert—on the basis of my experience in recent years—that the zoogeographical literature of temperate seas will have to be no little modified as a result of underwater observations by the biologists who have taken to the sea in the uniform of the frogman. I am equally certain that these scientists will broaden our knowledge of the ecology of the shallow, subtidal regions of the world sea.

Using self-contained underwater breathing apparatus—Scuba in short—my colleagues and I have made extensive observations of the various types of marine animals that may be found from the line of the lowest tides to a depth of about thirty meters along the coast of southern California. During each descent into these shallow waters, we encountered more and more unfamiliar species, especially among the rock-inhabiting faunas. It soon became clear that we were investigating an almost untouched domain of the sea: untouched, not from lack of interest, but simply because of its previous inaccessibility. For years biologists have investigated the life of tide pools or, aboard ships, have scraped and chewed at the ocean bottom with dredges, trawls, and grabs. But they were never able to bring their zones of investigation together—particularly in rock regions, from which dredges and grabs are unable to remove satisfactory samples. Scuba techniques, however, now permit us to close this gap in our knowledge. For this reason I have come to refer to this relatively narrow strip of the ocean bottom—bounded on the shore by a line a little below the lowest tides and on the seaward side by an arbitrary line at a depth of approximately fifty meters—as the Scuba Zone.

We are all aware that physical factors of the environment, such as temperature and salinity, exert important influences upon the distribution of marine organisms. But any biologist who undertakes submarine study will also be impressed by the definite and predictable relationship that exists between the composition of the fauna and the nature of the bottom deposit. Communities of organism on rock are remarkably different from those on soft bottoms. It soon became evident to us that the rock fauna themselves varied considerably when the substratum changed from siltstone to sandstone or to basalt, while the soft bottom faunas changed with shifts from mud to sand or gravel.

BIOLOGICAL oceanographers subdivide the benthos (bottom-dwelling animals) into two major groups: The group with which we shall be most concerned here is known as the epifauna—those animals that live i
Biologists

In shallow, offshore waters lie fertile areas for study

By Willis E. Pequegnat

One cannot draw a major line of separation between the kinds of animals belonging to the epifauna or to the infauna. Even though clams, snails, annelid worms, and starfish, for example, exist in both groups, we can sharpen the faunal differences by restricting ourselves to lesser categories of classification. Thus, many species and even genera of clams, worms, and the like are restricted to one group or the other. Generally speaking, it is even possible to state that there are more sponges, hydroids, and coral coelenterates, crinoids, barnacles, and sea cucumbers in the epifauna, while there are more varieties of clams, sea pens, brachiopods, and pogonophorans in the infauna.

Limitations of space and of species superiority create a degree of population complexity in the epifaunal domain that is unmatched by the infaunal populations. In many instances, not only are the epifaunal species crowded closely together, but the number of individuals of each species is also remarkably large. As a result, individuals of some sessile species form thick crusts upon the submerged rocks. In turn, the labyrinthine channels among the incrustations of these anchored animals provide suitable microenvironments for many sedentary or mobile animals, such as worms, snails, and crabs.

Up to now we have concentrated our attention upon silstone reefs, which are rather common in the Coral del Mar area. Even with this limitation, we have been overwhelmed by the number of unfamiliar species that were collected. Some of these species have proved to be new to science, and we have already named several of them (Pacific Science, April, 1960). Other unfamiliar species proved to be
rhapsy on the infauna, headed by the papers of C. G. Joh. Petersen of Denemark and extended by Gunnar Thorson, is voluminous. A comparison of Petersen’s work with Gislen’s will document the greater complexity of the epifauna. Petersen was able to reduce his delineation of the infauna of the Baltic and the adjacent North Atlantic to only nine communities of animals, some of them very limited in range. Gislen found it necessary to describe some forty epifaunal communities in Gullmar Fiord alone.

We have established a method that we believe gives a fair approximation of the numerical distribution of species on the siltstone reefs we are investigating. Our equipment permits us to remain submerged for at least one hour at most depths in the Scuba Zone. Metal rings, which enclose an area of one-tenth square meter, are fixed against the reef and all the organisms within the perimeter of the rings are removed with hammer and chisel. All materials, which frequently include large chips of rock with burrowing species, are placed immediately into canvas bags and taken to the laboratory. There, the species are identified and all the individuals are counted, measured, sexed, and, in some instances, weighed. Large species—such as gorgonian corals, sea urchins, starfish, and the like—are counted in the field by sampling random parts of the reef with one-meter rings. Occasionally we just count, especially larger fish.

During recent months, under a grant from the Office of Naval Research, we have applied this method to the study of two siltstone reefs situated in the open ocean just southeast of Newport harbor, California (illustration, pages 8–9). The long axes of these reefs run parallel to the shore. The first reef is 200 meters and the second 500 meters offshore; we refer to them as Reef 200 and Reef 500 respectively. These two were selected for study because of the depth relationships that they possess. Reef 200 rises from a sand bottom at a depth of seventeen meters to a rocky ridge just two meters below the surface. Reef 500 projects upward from a depth of fourteen meters to a flat rock surface. The overlap of depths between the bottom of Reef 200 and the top of Reef 500 has proven to be the most valuable relationship.

Most of our discussion here will be restricted to Reef 500. About eight kilometers long and varying from zero to a few meters to eleven meters in width, Reef 500 has a minimal area of 1,200 square meters.

Up to now, 330 described species of organisms—not including the protozoans, the more primitive flatworms, the nematodes, the annelids, and the small crustaceans—have been tested on Reef 500. Nor does this list include the many species of sponges, salps, and ectoprocts that we have been unable to identify. Of this total, 105 are invertebrates and 228 are fish. In strong contrast to Reef 200, Reef 500 is devoid of large sea mammals. This may account for the absence of albatrosses on Reef 500 in contrast to their abundance on the other reef. Additionally, the breakdown of the numbers of invertebrate species by phyla shows:

<table>
<thead>
<tr>
<th>Phylum</th>
<th>Reef 500</th>
<th>Reef 200</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porifera</td>
<td>36</td>
<td>2</td>
</tr>
<tr>
<td>Coelenterata</td>
<td>31</td>
<td>2</td>
</tr>
<tr>
<td>Platyhelminthes</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Nemertea</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Sipunculoidea</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Ectoprocta</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Endoprotura</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Mollusca</td>
<td>78</td>
<td>9</td>
</tr>
<tr>
<td>Annelida</td>
<td>47</td>
<td>5</td>
</tr>
<tr>
<td>Arthropoda</td>
<td>34</td>
<td>2</td>
</tr>
<tr>
<td>Echinodermata</td>
<td>19</td>
<td>2</td>
</tr>
<tr>
<td>chordata</td>
<td>13</td>
<td>1</td>
</tr>
<tr>
<td>Totals</td>
<td>305</td>
<td>31</td>
</tr>
</tbody>
</table>

The paucity of literature treating the epifauna of submarine rock formations served to document the fact that we know really very little about this region of the sea, perhaps even relatively less than we already know about the sea’s abyssal depths.

Torsten Gislen’s report (1929) on the epifauna of Gullmar Fiord, in Sweden, is the only comprehensive record of diving observations (Gislen used helmet gear) to appear in the century that separates the first observer in the field—Milne-Edwards, who made some underwater studies off Sicily in 1845—from the postwar world. Studies in the 1950’s and later, by Drach in France, Riedl in Austria, Kitching in England, and several workers in the United States, are limited in scope. In contrast, the bibliog-
An intelligible portrayal of the relationships that exist among this vast array of invertebrate species and between them and the physical environment is difficult to accomplish. The problem has two facets: first, the structure of this vast assemblage, which will include the physical relationships among the species and how they are distributed over the substratum; and, second, the functional relationships that exist both among the species and between them and the physical environment. Here, we call concern ourselves with the first, structural aspect. Two terms will aid us in doing this—the first is the "community," a term that the ecologist uses to describe any natural assemblage of organisms existing as a result of common reactions to the basic physical characteristics of their environment. The second the "zone," a term that is often used loosely, although it ordinarily conveys the conception of some kind of vertical placement—either of organisms or of environmental factors. The data obtained from field observations and from laboratory analyses now us to define a system of vertical zones that reflects the general placement of the totality of life on and adjacent to these rock reefs.

Most compelling observation—which led to our delineation of our separate zones—is that a marked gradient of reduction in the amount of life (the "biomass" of the ecologist) occurs from the top to the bottom of these siltstone reefs. This is to say that, in general, there are more species and individuals residing on a unit of area at or near the top of a reef than at the mid-point, and more at the mid-point than at the bottom. The three zones of the reef proper were used to reflect this observation: the upper hyperbenthic, mesobenthic, and hypobenthic denote the relative numbers of species and/or individuals living on a square meter at the top, the middle, and the lower part of the reef.

The parahypobenthal zone was so named to indicate that it existed on the level bottom alongside the hypobenthal region of the reef. It was a temptation at first to attribute the reduction gradient to one of the usual indirect effects of increasing depth (light intensity, temperature), but comparisons of laboratory data between Reefs 200 and 500 proved this conclusion untenable. Reduction gradients were observed on both reefs, but there is a richer fauna at the top of Reef 500 than at the bottom of Reef 200, even though these two zones lie at the same depth. It appears now that the principal cause of this biological gradient is the change in water movement, which influences the distribution of food around these reefs. This will be discussed more fully in the second part of this article, in the May, 1961, Natural History.

Some species are confined to a single zone, but most are not. Yet when a species does occur in more than one zone, it will achieve a peak density (numbers of individuals per unit of area) in a single zone. This can be observed in the frequency curves of a few examples (illustrations, pages 10-11). Thus, an assemblage of species that together reach maximal densities in, say, the hyperbenthal zone, is replaced by another assemblage in the mesobenthal and other zones. Besides changes in density, we found that changes in relative size of individuals occur when a species exists in more than one zone. The same is true of growth form, the niche occupied, and the relative age of individuals; in some mobile species, for example, the young will reach maximal densities...
in microenvironments quite different from those occupied by the adult.

Our most shallow region, the perbenthal zone, covers the per reaches of these siltstone reefs, a cap. On Reef 500, the shallow part of this zone (ten to thirteen meters) support a thick crust of the fixed corals Chama pellucida. On Reef 200, a similar but less solid crust of bivalve mollusks, composed of the mussel Mytilus edulis, occupies the corresponding position on the reef. Changes in depth of these two mollusks that occur variations in depth are strikingly shown below:

<table>
<thead>
<tr>
<th>REEF 200</th>
<th>Mytilus</th>
<th>Chama</th>
<th>REEF 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth in Meters</td>
<td>Av. per Sq. Meter</td>
<td>Depth in Meters</td>
<td></td>
</tr>
<tr>
<td>2-3</td>
<td>10,000</td>
<td>1,800</td>
<td>10-11</td>
</tr>
<tr>
<td>4-5</td>
<td>1,000</td>
<td>300</td>
<td>12-12</td>
</tr>
<tr>
<td>6-7</td>
<td>400</td>
<td>150</td>
<td>14-14</td>
</tr>
<tr>
<td>8-9</td>
<td>0</td>
<td>5</td>
<td>16-16</td>
</tr>
<tr>
<td>10-11</td>
<td>0</td>
<td>0</td>
<td>17-17</td>
</tr>
</tbody>
</table>

It is evident that both these mollusks occur over a considerable vertical range, but it is to be noted that 90 percent of the total population will be found in the upper three meters. It may note also that in the hyperbenthal zone individual Chama ave four centimeters in diameter and occur in dense stratifications as much as forty-five centimeters thick. In the mesobenthal zone, their diameter drops to two centimeters and clumps give way to two-dimensional aggregations. In the hypobenthal zone, only isolated individuals, a centimeter in diameter, are found.

The inexperienced eye would be unable to discern the presence of these thick Chama communities: they are often covered by a dense growth of amorphous sponges, plumose anemones, delicate ectoprocts, and small red algae. Here and there, the silt is dominated by the barnacle Balanus tininnabulums (averaging 1,200 individuals per square meter) or by beautiful, pink anemone-like coelenterate Corynactis californica. In some places, this coelenterate forms colonies that attain an average density of 3,400 polyps per square meter.

Adding to the complexity of life is a mosaic of color: the bright polychaetes—usually orange or purple—of the large, feather duster worm Etopo styli polymorpha, and of another...
Anemone-like Corynactis californica is a coelenterate of the hyperbenthal zone. It may form colonies, as shown, averaging 3,400 polyps a square meter.

Feather duster worm, center, is in a clump of Chama pellucida. The worm, Eudistylia polymorpha, has tentacles that are frequently orange or purple.

At other points in the hyperbenthal zone, especially where turbulence is extreme, the Chama community gives way to the tube mussels 

Cetes squamigerus or to dense growths of the magnificent orange argonian coral Muricea californica, where the turbulence is too moderate to either of these or for Chama, we find soft mats, five or six centimeters thick, composed of the amorphous sponge Lissodendoryx noxiosa, the stinging clam Hiatella arctica, and the tall, feather-like hydroid Plumularia setacea. Under optimal conditions, these three species and others, constant associates; the sponge creates a matrix in which the clams setle, with only their siphons protruding; the stalks of the Plumularia grow above the matrix surface from horizontal runners buried in the sponge; a delicate ectoproct like 

Ectoproctina and numerous small, red algae complete a miniature forest, through which minute worms and crustaceans scuttle in a never-ending search for food and refuge. This community may cover as much as 60 per cent of a square meter, providing a haven for 1,000 or more clams and an immense number of stalks of the semimicroscopic hydroid and ectoproct.

If one moves down the side of the reef to the mesobenthal zone, the walls give way to distinctly different types of animals. For the most part, the mesobenthal zone is covered to vertical walls at intermediate depths. Here and there these surfaces are broken by narrow ledges, vertical
Zoanthid Parazoanthus lucificum lives on skeleton of a gorgonian coral, crevices, and even small grottoes. One becomes aware instantly of a reduction in the water turbulence.

This second zone averages about seventy-five species per plot. So far as growth form is concerned, the compact incrustations of the hyperbenthal zone are replaced by open aggregations of markedly smaller organisms. The most salient external characteristic of this zone of Reef 500 is a luxuriant growth of calcareous ectoprocts. Large areas are dominated by such beautiful species as the pilledar colonies of Diaperocenia californica. These open thieckets of lime provide a haven for small brittle stars, annelid worms of diverse feeding types, miniature hermit crabs, and dwarf snails. These species form a cosmos of their own but, as we shall see later, they depend upon other parts of the reef's ecosystem for their existence. Certainly not all the species of the mesobenthal zone are small.

A very conspicuous component is the zoanthid colonial cocolenterate Parazoanthus lucificum, a colonial species that lives upon the skeleton of the gorgonian coral Muricea fruticosa. The bright yellow polyps of Parazoanthus, which look like miniature sea anemones, are closely packed upon the gorgonian. It is evident that the zoanthid does not await death of the gorgonian before making use of part of its skeleton, but we are not yet certain how it accomplishes the aggression. The discovery of this species at Newport harbor was of special interest: the genus Parazoanthus had never before been observed along the entire west coast of the Americas. Furthermore, we found P. lucificum to be brilliantly bioluminescent, flashing a bright, blue-white light upon stimulation. This is a trait that had not previously been observed among the zoanthids. Of considerable interest also is the fact that the gorgonian, M. fruticosa, achieves maximal density in the next lower, hypobenthal zone, but the zoanthid does not attack it at this low level.

Another characteristic species of the mesobenthal zone on Reef 500 is the stony coral Coenocyathus bowersi, which belongs to the same order of coelenterates as the reef-building corals of the tropical seas. Even in our relatively cold waters, this species produces massive colonies, of which the greater part are composed of the calcareous cups from which the beautiful, purple polyps arise. Many of the vertical crevices in this zone support one or more of the giant scallops Hiatites multirugosa, cemented to the rock by one valve. Its rich orange mantle contributing regally to the spectrum of submerged color. Here we find also the largest dorid nudibranch (a snail without shell) of this region, the orange-and-black Anisidoris nobilis, which measures up to thirteen centimeters in length. These large individuals are observed only during the winter months, when they are engaged in taching their yellow ribbons of color in spirals to the reef. Following to the adults, swim freely in the surface water, where they feed upon plankton, grow, and eventually return to the bottom. The tiny and slender shell-less nudibranchs continue to grow rapidly until, by late fall, they are ready to begin their reproductive cycle all over again.

Even in such a brief list of the mesobenthal zone's species, it is not unusual to find reference to small fish—the banded goby Lythrinus zebra, which measures no more than an inch in length as an adult. A rare species of the same genus is found in the zone below, but these two species are rarely observed together.

Farther down the vertical walls of the reef, we pass into the hypobenthal zone, the domain of a rather impoverished fauna, which exists within a few meters or so of the bottom. Wim movement is so slight in this region that we have come to refer to it as the "zone of quiet water."

The hypobenthal zone is characterized by a reduced number of species.
per square meter—averaging about fifty-five—and by a general reduction in the number of individuals. Many rock surfaces are nearly bare, covered only by a thin crust of coralline algae, colonies of small barnacles, or solitary corals. Nonetheless, some species attain their maximal densities in this zone, and some are quite large.

Among these characteristic species of the hypobenthal zone are the solitary coral Paracyathus stearnsi, and the related semisolitary Astrangia lajollensis. Here, too, we encounter the greatest development of the gorgonian coral Muricea fruticosa, the brilliant red sponge Cymmon neon, small individuals of the barnacle Balanus trigonus, as well as the much larger sea urchins Strongylocentrotus franciscanus and Centrostephanus coronatus, and the sea cucumber Parastichopus parvimensis.

The hypobenthal zone lacks the incrustations that have been considered characteristic of the hyperbenthal and mesobenthal zones. The few bivalves that are found here are either shallow burrowers or types that feed in a manner that rules out crowding; most of the ectoprocts, with the notable exception of the beautifully sculptured Cellaria mandibulata, form only thin films over the rock surfaces in the hypobenthal zone.

Although this zone is not as colorful as the others, it does boast one jewel in the form of the tiny goby Lythrypnus dalli, whose coral-red body is crossed by a few V-shaped blue bars. Although formerly considered rare, this species is much more abundant than its mesobenthal relative. Indeed, we must consider it one of the most common fishes of Reef 500; it attains densities of twenty per square meter, especially in October when the tiny young, scarcely more than a quarter of an inch in length, begin to appear in the open. At this time, its total population on the reef probably exceeds 4,000 individuals. Its habit of darting behind the quill-like spines of the sea urchin Centrostephanus proves most trying to the photographer in quest of a close-up.

Finally, we may turn to the parahypobenthal zone, which forms a region of transition between the reef base and the level bottom scarcely more than a meter or so in width. We may expect to find here some species that are related to the infauna, others that are doubtless epifaunal (especially when rock debris occurs at the base), and still others unique to this transition area. These species occupy three easily discernible microenvironments: the level bottom itself; the upper surfaces of small rocks; and the area beneath such rocks.

If we limit our discussion to species that are seldom or never found on the reef proper, we can say that typical plots in the parahypobenthal zone support an average of only twenty-five species per square meter. One characteristic species of this zone is the handsome burrowing anemone of Reef 500. Tentacles of polyps are protruding fully from calcareous cups.

Botranthus benedeni (whose delicate tentacles look like harmless, tapered tendrils until some food particle brushes by and they whip into action, pulling the morsel to the mouth). The large hermit crab Paguristes ulreyi, which lives in the shell of the snail Kellettia, must be included, as must smaller snails—of which Burchia, Conus, and Fusinus are representative. Here, too, we find the small, white sea urchin Lytechinus anamesus, which travels in herds that are as voracious in their underwater way as are army ants or locusts on dry land. No organic material that remains immobile will escape these little scavengers as they travel over the ocean floor like miniature tanks. Guided by olfactory receptors around the mouth and on the tube feet, the sea urchins swarm over any carcass and can strip even a large fish to a pile of bones in a few hours.

Other characteristic species of the parahypobenthal zone are the tube-building annelid worms Diopatra ornata and Pectinaria californiensis. Beneath the surface of the sediments, one will find dense populations of the burrowing sea cucumber Leptosynapta inflata. The tops of rocks will often support still another gorgonian coral Lophogorgia chilensis, whose white polyps stand out in bold relief against the scarlet covering of the skeleton. Beneath the rocks we find aggregations of serpent stars, of
Dr. Willis Pequegnat, a zoologist may rightfully claim total immersion in his subject, the research for which required mastery of Seabed diving an submarine photography technique. He is an Associate Program Director with the National Science Foundation, which the largest is *Ophioderma p. amensis*. This species, which attains a diameter from arm tip to arm tip more than twenty-four centimeters, is another effective scavenger. The pent stars leave their hiding places in dusk to deploy ranks in even space around the base of the reef, waiting for food bits to drop from above.

We have observed that dense aggregations of the individual species are characteristic of the hyperbenthal and, to a lesser extent, of the mesobenthal zones, while they are not found at all in the hypobenthal zone. In accord with this, the totality of life tends to reduce markedly as we move from the top to the bottom of the reef. And we have observed that related species of animals may replace one another in success from top to bottom. We saw, for example, that one kind of sea cucumber reached its peak density in the hypobenthal, but was replaced by others in the hypobenthal and parahypobenthal zones. Later we shall see if these three species possess remarkably different feeding methods.

These differences in feeding habits may be the key to this and of other patterns of species complementality. No single physical or biological factor can account wholly for the distribution of food, but we are inclined to stress the importance of current and turbulence. No matter how favorable all other factors may be at a given place, the availability of food in the right kind and in ample supply will be the *sine qua non* of ecological distribution in a given biophysical complex. The implications of this section will be assessed in greater detail by next month, when we shall describe the sea, how animals adapted to feed upon it, and attentively trace the relationship between the sun and the hordes of animals we found on our siltstone reef.

*(To be concluded in May)*

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The Unearthly Visitors

Meteorites are samples of outer space

By Brian Mason

Outer space is a theme that, in its many variations, affects all of us today. Plans are being made to send manned rocket vehicles to the moon, and ultimately to neighboring planets. The exuberant would extend man's range even farther, to the distant stars. Seekers after adventure now look to interplanetary travel, rather than to our own peaks and poles, as holding the lure of the unknown.

The potpourri of man-made missiles fired into space might be considered a form of terrestrial retaliation, for the earth has been bombarded from outer space since the beginning of time. Fortunately, most of these exotic missiles burn up in the atmosphere and reach the ground as fine dust. However, a larger piece occasionally survives its perilous passage, strikes the earth, and is eventually collected. Such bits and pieces of extraterrestrial matter are known as meteorites. Geologists collect and preserve them as the only tangible samples of the great universe around us.

We are fortunate that the frequency of fall is very low. Otherwise, more of us would suffer the rare and undesirable experience of Mrs. Hewlett Hodges of Sylacauga, Alabama, who, on November 30, 1954, was bruised when a meteorite tore through the roof of her house and struck her on what was described as her upper thigh.

There are well-authenticated records of meteorite falls as far back as
the fifteenth century, but our ancestors were skeptical about reports of stones falling from the sky; and it was not until early in the nineteenth century that scientists were convinced of the fact that objects from space do fall on the earth's surface. In this country, the fall of more than 300 pounds of stones near Weston, Connecticut, at 6:30 A.M. on December 14, 1807, was extensively reported by Professors Silliman and Kingsley of Yale University. However, skepticism was rife. Even the then President, Thomas Jefferson, ventured the opinion that it was easier to believe that Yankee professors would lie than to believe that stones would fall from heaven!

Once it is admitted that falls actually occur, the question naturally arises: what is the frequency of meteorite falls? This is not an easy problem to resolve. In most places, there is no one to observe a fall when it occurs, and the probability of the meteorite's being picked up later depends on many chance factors. A study of the frequency of meteorite falls in densely populated areas shows that the average yearly rate of fall probably lies between 0.3 and 1.0 per million square kilometers. This would mean, for example, between two and eight falls a year in the continental United States.

Occasionally, there have been falls of large meteorites that must have forced themselves on the attention of any observer within hundreds of miles of the spot. Such a case was that of the Tunguska meteorite, which struck an uninhabited region of northern Siberia on June 30, 1908. The impact was felt as an earthquake along the Trans-Siberian Railway, five hundred miles to the south, and the forest surrounding the point of impact was felled radially outwards for a distance of forty miles. Meteor Crater in Arizona, 4,000 feet across and 600 feet deep, is evidence of a similar fall of a large meteorite in this country during prehistoric times. Meteorite craters are also known from other parts of the world, generally in deserts, where erosion is very slow and the crater survives. The largest meteorite on exhibit is the Cape York, which weighs thirty-four tons. It was brought back from Greenland by Admiral Peary in 1896, and is now in The American Museum-Hayden Planetarium. The largest known meteorite is the Hoba iron, which still lies where it was found, on a farm in Southwest Africa; its weight, by estimation, is probably about seventy tons.

Meteorites are classified into three groups according to their composition: the irons, the stony-irons, and the stones. There is a possible fourth group, the tektites—small, glassy objects that have been found in isolated areas of Australia, Southeast Asia, Czechoslovakia, Texas, and Georgia. They differ from known terrestrial glasses but, since no one has seen one fall, their classification as meteorites is a subject of scientific dispute.

There are about 1,500 well-authenticated meteorites—using the term "meteorite" for a single fall. Each fall, however, may comprise many pieces. Tens of thousands of fragments have been found around Arizona's Meteor Crater, while the Holbrook, Arizona, fall of 1912 was composed of more than 14,000 individual stones.

A common misconception is that most, if not all, meteorites are iron. It is true that the largest meteorites are all irons and that, in museum collections, irons generally dominate. However, if we examine statistics of finds (meteorites not seen to fall), as opposed to those collected after having been seen to fall, we see a remarkable reverses.
the proportion of different types between the finds and the falls. The reason is not far to seek: The relative abundance of irons as finds is due to their being easily recognized as meteorites. However, a stony meteorite—unless seen to fall—could easily be overlooked. When we plot the finds of meteorites in the United States on a map, we might conclude that the Great Plains have been bombarded by a hotspring, while New England has been mysteriously spared. The reason that any stone on the Great Plains is likely to attract attention, whereas in the rocky terrain of New England it might be overlooked, is a very unusual stone indeed that receives a second glance. Thus we get a truer indication of the relative abundance of different types of meteorites from the relative proportions of those actually seen to fall. These figures show that the stones are far more abundant than the two other types of meteorites taken together.

Iron meteorites consist essentially of iron-nickel alloy—the average composition being about 91 per cent iron, 8.5 per cent nickel, and 0.5 per cent cobalt. All meteoritic iron contains nickel, and a test for this metal is useful for eliminating specimens of cast iron and similar material, which are sometimes mistaken for meteorites. The irons commonly contain small, rounded inclusions of troilite (iron sulphide) and schreibersite (iron-nickel phosphide). The metal generally shows a definite structure—known as Widmanstätten figures—that may be brought out by etching a polished surface with acid. The Widmanstätten structure is a network of bands, crossing one another in two, three, or four directions; the bands are composed of kamacite (a nickel-iron alloy with about 7 per cent of nickel) bordered by thin layers of the nickel-rich alloy taenite. The angular interstices of the network are filled with a fine-grained mixture of both kamacite and taenite, which is named plessite. This distinctive structure is the result of a chemical segregation after the metal crystallized. Originally the nickel-iron must have been molten, and then have solidified as large crystals. 

Journey's end comes for meteorite as workmen roll it down ramp to resting place at The American Museum, where it is displayed in Hayden Planetarium.

Stones are the most abundant meteorites. They also show the greatest variety in composition and structure. They are divided into two groups on the basis of structure: the chondrites and the achondrites. The first are so named because of the presence of chondrule, or chondrules—small (usually about one millimeter in diam-
Achondrite stone shows rough texture.

Chondritic stone has olivine, pyroxene.

Stony-iron, pallasite, contains olivine.

Black carbonaceous chondrite, above; Widmanstätten figures, below, in iron.

Upon mineralogical analysis, most chondrites prove to be a mixture of olivine and pyroxene, generally with between 5 and 20 per cent nickel-iron, about 5 per cent troilite, and about 10 per cent plagioclase (sodium calcium aluminosilicate). Many achondrites are similar to chondrites in composition, except that they contain little or no nickel-iron. Some, however, contain a considerably larger proportion of plagioclase and are thus known as basaltic-type achondrites, since their composition is like basalt, a common volcanic rock.

One small group of chondrites is remarkably different in its chemistry and mineralogy. Known as the carbonaceous chondrites, they contain a notable percentage of free carbon, which gives them a black, sooty appearance. While all other meteorites contain essentially no combined water, the carbonaceous chondrites contain 10 per cent to 20 per cent. They also contain organic compounds in small amounts, as well as free sulphur, calcium and magnesium sulphides. Instead of olivine and pyroxene, the silicate mineral is largely serpentine (a hydrated iron-magnesium silicate). They contain no nickel-iron.

Only nineteen carbonaceous chondrites are known: all of them were seen to fall and were picked up soon after. Indeed, if they were not collected immediately after falling, they will have survived very long: of all of them it is recorded that, when placed in a glass of water, it disintegrated and gave off a nasty odour. This stench was probably sulphurated hydrogen, produced from carbonaceous compounds. The first known carbonaceous chondrite fell at Alais, in France, on March 15. It was sent for analysis to the famous chemist Berzelius, who expressed no doubt as to its meteoritic origin, but it was so different in composition from all other meteorites.

However, the obvious differences between the carbonaceous chondrites and what we may call the olivine-pyroxene chondrites have obscured a remarkable similarity. Dr. Willard, a Finnish chemist who has analysed many meteorites, pointed out in 1916 that, if analyses of these two types of chondrites are recalculated on a
- carbon, oxygen- and sulphur-free

is, their elemental composition is very similar. This is to say that the chemical composition of the common olivine-pyroxene chondrite is that of carbonaceous chondrite from which later, sulphur, carbon, and some oxygen have been removed. The conversion of a carbonaceous chondrite may be produced by a natural heating process. Serpentine decomposes on heating above about 500°C., to yield olivine and pyroxene. If carbon is present, a natural smelting will take place, reducing some of the combined iron to metallic iron—anther constituent of olivine-pyroxene chondrites.

Having described the principal mineralogical characteristics of meteorites, we may now consider their origin. H. A. Newton, as long ago as 1886, summarized the numerous theories in the following manner: "They came from the moon: they came from the earth's volcanoes: they came from the sun: they came from Jupiter and the other planets: they came from the destroyed planet: they came from comets; they came from the surrounding mass from which the solar system has grown; they came from the fixed stars: they came from the depths of space."

Truly a plethora of possibilities, one of which, however, can reasonably be eliminated. Origin from the earth's volcanoes is inconsistent with meteorites' composition, which, except for the small group of basaltic achondrites, is different from all volcanic rocks. Moreover, volcanoes, though powerful, do not produce enough energy to put rocks into orbit! It is also difficult, if not impossible, to derive meteorites directly from the sun, the moon, Jupiter or the other planets. Nonetheless, meteorites presumably originated within our solar system since, like all other bodies in this system, they revolve about the sun. For many years it has been assumed that meteorites are fragments of a disrupted planet that once existed between Mars and Jupiter. This region of the solar system is occupied by innumerable small objects (some of them as much as three hundred miles in diameter) known as asteroids.

The origin of both meteorites and asteroids from a disrupted planet implies that the disruption probably took place early in the evolution of the solar system and that most of the fragments
were swept up soon after. Such a disruption would probably have bombarded the other planets with fragments very much larger than the average meteorite of the present time. To be sure, no evidence of bombardment on such a scale has been recognized yet in the rocks of the earth's crust, some of which date back over three billion years. Still, the innumerable craters on the moon are thought to be due to the impact of meteorites: in the absence of an atmosphere, little weathering or erosion takes place on the moon, and these craters have thus been preserved unchanged.

Irons, stony-irons, and achondrites can be explained readily as originating from the disruption of a planetary body. Like the earth, such a body would presumably be differentiated by the force of gravity into an iron core and a stony mantle, the stony-irons coming from a transition zone. Certain features of the chondrites, however, are not so easily accounted for. The composition of the carbonaceous chondrites shows that they have never been exposed to temperatures above 500°C, and have probably always been at much lower temperatures. Further,

**Dr. Mason, Curator of Mineralogy, has based this article on studies of the extensive collection of meteorites belonging to The American Museum.**

the texture and structure of both carbonaceous chondrites and olivine-pyroxene chondrites indicate that they have not originated in any body with a considerable gravitational field. Many of them are very porous and friable—some to such a degree that they can be crumbled in the hand—a condition that indicates that they were not consolidated under pressure. The nickel-iron in the chondrites, moreover, is intimately mixed with low-density silicate minerals and shows no sign of gravitational segregation.

One of the recent discoveries of astronomy is that outer space is dusty. It is now believed that more material exists in the universe in the form of dust than is aggregated into stars. The composition of this dust is unknown, but it is presumably made up of the same chemical elements that compose the larger bodies. Perhaps the carbonaceous chondrites are representative of this primordial dust.

We have seen that heating processes would convert carbonaceous chondrites into olivine-pyroxene chondrites. Consider the possibility then that the solar system may have originated as an immense cloud of primordial dust, which gradually cohered in moderate-sized masses, of which chondritic meteorites are a sample. These masses—"planetesimals," as they have been called by Chamberlin and Moulton—then aggregated to form the planets. Aggregation into such large bodies would produce heat sufficient to melt them at least partly, and this melting would result in a gravitational separation of the metals from the silicate.

In this view, the breakup of a planet—presumably situated between Mars and Jupiter—produced the asteroids, some fragmental representatives which still remain in the earth's gravitational field and eventually landed the irons, stony-irons, and achondrites. But the carbonaceous and olivine-pyroxene chondrites, on the other hand, would not have derived from the planetary disaster. Instead, in this view, these meteorites would represent the "fossil" planetesimals leftovers—in considerable number—from the initial cloud of cosmic dust from which our solar system grew.

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*Aerial view of Meteor Crater, Arizona, above, shows the deep gouge left by impact of a meteor during prehistoric times. At right, the camera looks north, from rim to rim across the 600-foot-deep crater, a distance of 4,000 ft.*
A primary purpose of The American Museum of Natural History is to contribute to the understanding of man's place in the world of nature and to communicate that knowledge to the public. The Museum's newest exhibit, which shows man as a physical entity, dramatically furthers that purpose. It is the first in a series planned to present organic man and his culture.

The exhibit, called the Hall of the Biology of Man, consists of three subdivisions, two of which were opened to the public late in March. The first section is concerned with human evolution and the relationship of man to organisms that preceded him in time. The second section is devoted to the development of the human organism itself—from the basic unit of life, the cell, to a functioning body of infinite complexity. The third will show man as a member of a biological group with its own environment.

Obviously, the scope of such a subject poses stringent exhibition requirements. To this end, new techniques and materials have been utilized, and old ones put to new uses. One example lies in etching figures on a series of clear plastic sheets, which are then superimposed on each other. When edge-lit, the sheets transmit light to the etched areas, producing the illusion of movement within the figure being displayed.

 Readers of NATURAL HISTORY are invited to preview high lights of the exhibit on these pages.
Evolution, from invertebrates through vertebrates, mammals, primates, and man, is dramatized in varicolored tiles.
Nervous system was constructed in miniature with strands of brass wire. The brain and spinal cord are of wax.

Panel being installed shows in detail multiple movements made by leg and pelvis in process of taking one stride.

Leg articulation, right, is explained by bone in foreground, behind which are metal cutouts against a painted background.

Five-by-eight-foot photomural of human ovum and sperm begins exhibit demonstrating development of embryo.
Plaster model of human birth, below, is culmination of a series of exhibits on history of a new organism's development.

Routing on laminated sheets of clear plastic are edge-lit to produce life-sized model of human circulatory system.
Plastic, wax, and wire were utilized in display showing how cells are organized into tissues and structures, including the trachea, spinal cord, bone, and skin.

Model of circulatory system is made of successive plastic sheets. A light on edges makes heart beat and simulates movements of blood.

Routing is done with fine engraving tools on successive acrylic sheets. These, superimposed on each other, are fastened together for final display.
If you ever wished you were an archaeologist—

you will want to read "Archaeology as a Career" in the Spring 1961 issue of ARCHAEOLoGY, which is just out. ARCHAEOLoGY is a quarterly magazine produced by specialists expressly for amateurs. Every issue contains numerous articles written in non-technical language and lavishly illustrated, frequently in color. ARCHAEOLoGY reports the latest discoveries in every part of the world.

Also in ARCHAEOLoGY's Spring issue: excavations in Greece, Turkey, Germany, Italy, Barneo. Following issues will take our readers to Iraq, Spain, Denmark, Hawaii, Ecuador, Peru, Panama and our own west coast. The Winter 1961 issue will be devoted to the pressing problems of salvage archaeology all over the world. If you act quickly, you can start your subscription with the Spring issue.

Our readers write us:

"I count ARCHAEOLoGY as one of the very top pleasures of being an armchair archaeologist..."

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"For a layman like myself, I think this is the finest publication on the subject that I have ever seen."

(Published by the Archaeological Institute of America)
STREAM EDGES

Stream's relation to its shore or bottom may sharply affect man

By E. LAURENCE PALMER

IN AND OUT OF NATURE, the most dynamic, interesting, and challenging situations are usually found where different elements meet. Hunters find their greatest rewards at the juncture of field and forest. Trappers succeed best where land is bordered by water. Men find their most wholesome enjoyment of life where they can mix the satisfactions associated with periods of rest with vigorous physical exercise, or muscular activity with mental stimulation. The greatest rewards in scientific research are in explorations of the border territory between the biological and physical sciences, particularly when such studies satisfy human demands for the practical, mental, moral, and aesthetic aspects of life.

In this discussion we will examine the events that take place at the points where a moving stream of water makes contact with a fixed bottom or shore.

There are good reasons why major centers of human population are usually located at points where the land meets a stream of water—a stream that serves to bring in wealth and take away the wastes of civilization. At the water's margin are to be found the roots of both the problems and the opportunities of the world's human races. Wars have been, and will be, fought by people who hope to maintain or gain access to flowing water. Similar wars are also fought by mammals other than humans, and by plants and other living organisms. There must be a "give and take" all along the line, and rarely, if ever, can we use a ruler to map the course of a stream—or, for that matter, a society, human or otherwise.

In this insert we are concerned with the dynamics of a moving stream, its fixed and confining earth, and with the activities taking place in the neighborhood. A wall along the banks of any stream will enable the reader to enlarge on the information and observations presented on these pages; but it will be worth while to carry through some of the suggestions that follow.

Most people have difficulty resisting a temptation to throw objects like sticks and stones into an inviting body of water. We like to see the water splash, and find out whether the objects sink or float. Objects that are heavier than the volume of water they displace sink, while those that are lighter float. Floating objects in moving water constantly change their positions, creating an endless variety of new situations wherever they go.

Select, then, some stream a few feet wide where, for a hundred feet, the depth is relatively uniform and the speed of the water reasonably constant. At ten-foot intervals along the bank, place sticks, stones, or other distinctive markers. Above the first upstream marker toss an object into the water so that it will be carried along by the stream. A snowball or a small stick will serve the purpose. Then notice the number of seconds it takes for the floating material to move a hundred feet down stream. If you throw in several objects, it is unlikely that they will all move downstream at the same rate. You may determine the average rate of movement, but do not forget that movement is rarely uniform. Decide that on average, the water moves by a given point in the stream at a given number of feet per second.

To the tip of a pole—about the size of a fishpole—attach a string a few feet long. To the free end of the string tie a stone heavy enough to hold the string ve
ically in the stream with the stone resting on the bottom. At equal intervals on the string tie markers, so that you may easily measure the stream depth at any point. Imagine that a vertical sheet of water is moving downstream past any point, and determine the size of this sheet of water with the help of your measuring device. In this way you should have little difficulty in estimating the number of cubic feet of water passing a given point in one minute. Since there are 7.43 gallons in a cubic foot, you can approximate the number of gallons the stream carries per second, or per minute, if you prefer. This figure will be of importance to you in describing the stream with some degree of accuracy.

It is the moving wall of water that does much of the work in changing our stream edges. Some objects float in the current, and do little or no damage to the stream edge. Others remain fixed on the stream bottom without effect on the bottom itself, although they may smooth off the rough edges of objects passing over them. Much material bumps along the bottom and sides of the stream—and it is this that most affects the stream bed.

Since water is heavier than air, a stone submerged in water weighs less than it does in air, displacing the same amount of substance in either case. This means that a stream may move some remarkably “heavy” material. By observing the movement of substances along the bottom of a stream, you may roughly estimate the speed of the water in a stream. Here are some suggestions to aid your estimation of water speeds.

Water flowing at three inches a second, or about three-eights of a mile an hour, will move fine clay along the bottom of a stream, if the clay is loose.

A sluggish river, flowing at six inches a second—about three-quarters of a mile an hour—will be able to move fine sand along the bottom.

A river flowing at eight inches a second, or about one mile an hour, will move coarse sand.

A brook flowing at one foot a second—about one and one-half miles per hour—will move fine gravel.

A stream flowing at two feet a second, or three miles
an hour, will move loose pebbles one inch in diameter.
A swift stream, flowing at about six miles an hour,
will move ten-inch stones.
A torrent that flows at eleven miles an hour may move forty-two-inch stones.
Cloudburst waters flowing at twenty-two miles an hour
may move boulders weighing up to 250 tons.
The width of a stream, of course, affects the speed
of its waters at any given point, and the stream flows
more rapidly at its narrowest points. It is important to
realize this fact if for any reason it is desired to make
the stream co-operate in changing the nature of its bank.
It might be thought that, if the water in a stream were
moving at four miles an hour—at a speed about equaling
that of a good fast walk—a doubling of the stream's
speed would enable it to move objects weighing twice as
much. As a matter of fact, doubling the stream's speed
increases its carrying power not by twice, but by sixty-
four times. This means that if a stream were wearing
away its banks by moving pebbles weighing one ounce,
and its speed were doubled, it would be capable of
moving rocks weighing four pounds. If its speed were
doubled again, it would move rocks weighing 256
pounds. From these figures, it is obvious that the move-
ment of water over fixed earth may become a matter
of the greatest importance to humans.
Water, moving over the surface of sloping land, car-
rries with it materials that may be of great value to the
landowner. Such movements of small amounts of valu-
able soil may, over the course of time, prove more
significant than the spectacular erosion produced by
flash floods. Sheet erosion is not as noticeable as the
gully-type of erosion, but it may be even more wasteful.

It may be noticed, during a walk along a stream after
a heavy downpour, that the stream's color is not
uniform. The water flowing over mud or clay is of a
different color than that which flows largely over rock.
It may also be noticed that small streams flowing into
larger streams also vary in color, and that those coming
from sod-covered areas are clearer than those originating
in cultivated land lacking a binding sod. If you are a
fisherman, you have probably learned that the fishing
varies with respect to locality—the fish seem to know
that, where stones and debris are turned over on the
bottom of a stream, aquatic insects are washed from their
hiding places as items of food.
The management of stream banks is a science that
calls for the application of engineering, biological, and
other technical skills. For example, it is recognized that
the volume of a stream varies over the course of the year
and that the work done by a stream in flood may create
conditions conducive to the survival of useful fish if
times of drought. Stream bank managers know that
shallow, slowly moving, unshaded waters may become too warm for many species of fish, and thus they plan to provide needed depth, speed of current, and shade.

Generally speaking, the more important schemes employed in managing streams for fish include the digging of channels, to provide fish with an opportunity to move from a threatened area to a better one. Such channels guarantee that a fish may also have a sufficient volume of water in which to survive. Also employed are deflector dams of boulders, large stones, anchored logs, or even concrete walls. These latter serve to prevent dangerous undermining of stream banks, and also to allow undermining where it is wanted. The deflectors concentrate or dissipate the flow of water. Some are designed with holes in their bases through which a stream of water may flow at a high rate of speed to flush out the bottoms of downstream holes. Others have V-shaped tops that guide the fall of water to scour out downstream holes. Single-wing and double-wing deflectors provide a maximum of stream useful to trout in a given mile of stream bed.

A well-planned stream bank uses the anchoring qualities of plants that grow down to the edge of the water, and limits the access of cattle and other animals that may destroy the protective sod. Stream bank managers use plants to hold the stream in place, and to this end they may plant large numbers of willows to serve as soil anchors. The roots of the willows may also provide hiding places for fishes of different sizes and species, with the smaller surviving until such time as they might be of value as food for the larger. Fencing portions of the stream border also helps in anchoring the stream edge.

Dams may be useful in stream and stream bank management, and may be constructed of boulders, logs, or combinations of stone, earth, and wood. Parts of these dams may be modified to utilize the retained water for special purposes, although the dams serve primarily to store water against times of water shortage. Engineers know how to construct dams, which will build up useful accumulations of silt, or which, on the other hand, will keep such accumulations at a minimum. Some man-made dams rather closely resemble beaver dams, and make use of brush in their construction.

The building of structures designed to change the nature of a stream bank takes into account not only the large differences that may exist in a stream during the several seasons of the year, but also the expense and effort necessary to maintain them over a span of time.

The interests of different animals that haunt a stream bank may often conflict. Man, for example, may wish a mudbank to maintain a pond where his ducks may breed. Such banks may also provide ideal earth into which muskrats may burrow—but the muskrats cause major leaks in the dams, built by men at considerable expense in time, money, and effort.
Two-lined Salamander

It should be interesting to investigate the variety of holes to be found along and in stream banks, made by various organisms. Some of the holes may be underwater, some at water's edge, and others well above the water mark. The tabular matter accompanying this insert considers a number of these "hole-makers."

Underwater holes in streamside banks may be vital to mammals like beavers, which must reach their dens in a bank or in a house under the ice of winter. Such entrances may be at the deepest point in the waterway near the bank, and continuous use of the entrance may make the ice thin at that point. It is well to realize this fact when you start to walk around a beaver house in bitter winter weather! The underwater entrance allows the beavers to carry food into their dens and to attain a degree of safety from enemies. Muskrats, too, are able to reach their houses from underwater without risking exposure to their many enemies.

Many other animals use similar techniques. Crayfish may burrow in a stream bed in search of food and safety. Frequently, the resulting channels open up spaces through which a small stream of water may begin to flow, and the bottom of the stream is thus kept active in the production of small organisms important to the larger as food. Even small burrows may serve this function.

Many aquatic insects also burrow in the stream bottom, and some burrow into the banks at or above water's edge. All these burrows, taken together, create considerable changes in the stream bank. Turtles may burrow into the stream bed; some may occupy abandoned muskrat burrows along the bank. In some cases such used or abandoned burrows may be appropriated as shelters by the snakes that live in our waterways. In the South, where water moccasins are found, one should investigate the tenants of such burrows with respect!

Salamanders of a number of kinds frequently modify stream banks, even if in a rather modest way. Ordinarily, these small amphibians burrow in mud or under pebbles on the bottom; but wherever they go they may leave an open area behind them through which the water may increase its flow and consequently its work. Anything that disturbs the stream bottom or bank may, in the course of time, effect changes in the stream itself.

Not infrequently the muddied bottoms of streams provide ideal burrowing sites for many of the fresh-water mussels. The mussels supply food for fishes, which burrow in the mud in search of them; and in this way the mussels help to modify the stream bottom.

There was a time when the shells of fresh-water mussels were so abundant in our streams that they had a considerable economic value. "Pearl" buttons were cut from the shells, and from the resulting waste came material useful as an adjunct to poultry rations. Limes from the shells constituted a fertilizer for improvement of both the chemical and mechanical nature of agricultural soils. Since many of the fresh-water mussels spend a part of their life histories as parasites on fishes—particular species of mussels favoring particular species of fishes—some remarkable situations develop. Some of these are mentioned in the chart section of this insert. Heavy populations of mussels tend to build up the bottoms of streams in favorable places, so that we have "shoals" owing partly to their abundant presence. Some such shoals have had a bearing on power development along a number of American streams and rivers.

In the 106th insert of this series it was pointed out that some fresh-water mollusks are significant in their relation to public health, and it is probably true that the mollusks, which can change the courses of mighty streams, may in the long run be more important than great armies or great dams.

While problems of sanitation and economy, as they bear on stream banks, are important, they should not be allowed to become exclusive. A sandpiper runs along the edge of a stream. A kingfisher flies into its streamside nest, to the delight of those who enjoy watching stream banks for aesthetic reasons. Men consider the monetary promise of a stream flowing through a gorge, but they should also consider the song and antics of the water ouzel. Few who have watched this bird in its natural environment would hesitate to defend its presence, or would advocate its elimination in the interests of "progress." Less vigorous, but perhaps better known, are the phoebes that haunt walls of glens from coast to coast. Perhaps it is such glens that offer the greatest study rewards. Their waters run swiftly at times, and as a mere trickle at other times. Exhibited in the glen is the raw power of moving water—the power to scour, to develop plunge basins, to tear away vegetation. In its quieter phases, the water of the glen performs the slow steady, plodding work which may, over the course of the years, produce even more important changes.

Perhaps it would be of more value to study a single stream bed and compare it with one in which the stream waters flow over an entirely different sort of bottom, and with an entirely different volume and variation in flow. It should be remembered that this discussion dwells primarily on stream banks where the flow of water is
not strictly cyclic, as it is on a tidal flat. In our streams, any object that moves past a given point in the water-course seldom, if ever, returns.

In studying the management of the stream edge we must recognize that the edge is rarely stationary. It moves up the bank when in flood; down when in drought. While in tidewaters this movement is cyclic and can be predicted with great accuracy; in a stream this is rarely so. A fiddler crab at the edge of the tide burrows down as the tide goes out. When the tide comes in the crab emerges to roam, feed, and breed. A stream margin presents a different pattern. In time of flood, the plants and animals of the edge may be submerged or partly submerged for a few hours, days or weeks, and this period may be followed by a drought of indefinite length of time. Sometimes such submergences or exposures are accompanied by extremes of heat, light, and abrasion, further complicating the survival problems of the creature involved. This situation is met in part by the ability of some stream edge plants and animals to move as the need arises. On the other hand, many organisms can survive if one part of the creature can remain out of the water while another part is submerged. When a beaver dam is first established, the trees whose roots are at first submerged may appear to prosper, but if the submergence continues the roots cannot continue to function because the air has been cut off. Then, of course, the roots and the trees die—as you may see at the edge of any pond created by a growing beaver colony. If the value of the harvestable beaver pelts exceeds the value of the wood the colony may in time be considered an asset by the landowner. If not, then the work of the beaver must be considered as destructive unless other values change.

The 60th insert, published ten years ago, was titled "On the Level," and went into considerable detail about the use of dams in controlling the water level along streams. It emphasized the difficulties of managing this level so that the demands of flood control, of reservoirs, of power development, of navigation, and fish and wildlife management could be met with reasonable success. The conflicting interests of those seeking power, recreation, irrigation and flood control from a common stream call for ability to manage that all-important stream edge.

FACTORS finding expression in stream bank management are complex indeed. Water flowing steadily in and through an established irrigation ditch may do little damage, while other water moving with exactly the same speed over raw soil may be highly destructive. Water flowing over a hillside on which sod is well-established may do no damage whatever, while water flowing with equal speed down a similar hillside over unanchored soil may tear away useful earth and cover valuable land elsewhere with unwanted sediments. All of this makes the control of the waters’ edge a challenging, interesting, and important problem to anyone.
<table>
<thead>
<tr>
<th>Plant or Animal</th>
<th>Description</th>
<th>Range and Relationship</th>
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<tbody>
<tr>
<td><strong>White Willow</strong> Salix alba</td>
<td>Shakespeare says: &quot;There is a willow grows aslant a brook, that shows his hair leaves in the glassy stream.&quot; This tree may be over 100 feet high, with a trunk diameter to over 6 feet. Alternate leaves to 4 inches long, and ½-inch wide, dark green above and light beneath.</td>
<td>Native of Europe, but widely established in America. Seventy of more than 170 recognized species are found in America, thriving in moist, loose soil. Most closely related to crack willow or yellow willow. More than 20 species of trees. Family Salicaceae.</td>
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<tr>
<td><strong>Kentucky Bluegrass</strong> Poa pratensis</td>
<td>&quot;And I will give grass in thy fields for thy cattle, and thou shalt eat and be full,&quot; we read in Deuteronomy; and grass growing along stream banks helps keep water in its place. Tufted stems to 3-feet high. Flower-stem leaves to 6-inches long, ¼-inch wide, flat or folded, soft. Basal leaves larger.</td>
<td>Grasses include the cereals and much of the pasture crops. In nature they are closely associated with, but not related to, the legumes, to form the sods that are the soil. They provide forage which admits water and air and improves productivity. Some 3,500 species over world. Family Gramineae.</td>
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<tr>
<td><strong>Diatomaceous Oozes</strong> Diatomaceae</td>
<td>Rupert Brooke, in his poem &quot;Heaven,&quot; tells us that fish look ahead and: &quot;...somewhere, beyond Space and Time, is wetter water, slimmer slime.&quot; He recognizes the importance of the aquatic slimes that give a dangerous but important slimy surface to most fixed, solid surfaces under water.</td>
<td>Diatoms are plants belonging to the Class Bacillariaceae, essentially glass boxes containing plant material. With the valves symmetrical bilaterally in the Order Pennales, and circular or irregular in the Centrales. They occur in fresh, brackish, or salt water, and are usually mucus-imbodied.</td>
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<td><strong>Fresh-water Mussel</strong> Lampsilis siliquoides</td>
<td>Some stream margins may have muddy bottoms and slowly moving water. In these margins may burrow two-shelled mussels, or mussels. In this species, the two shells are about equal, 2 x 4 inches, hinged along straight edge, greenish, with eccentric ridges, a single fleshy, spade-shaped foot.</td>
<td>This is a mollusk of the Class Pelecypoda and Family Unionidae, and is a fresh-water species. Some species may be found in compact mounds of the bottoms of trout streams; others are limited to loose mounds of pond-bottoms. Usually lie largely buried in the mud with access to freely moving water.</td>
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<tr>
<td><strong>Fresh-water Shrimp</strong> Gammarus fasciatus</td>
<td>The plants that crowd the land in water at the edge of a stream often team with fresh-water shrimp that are to about ½-inch long, swim actively back foremost, may be pale green, tan, or almost white, and may show a rather conspicuous eyespot and waving legs, antennae, and other parts.</td>
<td>The animal belongs to the Crustacea, which includes crayfish, crabs, and lobsters. The family Gammaridae live in fresh water, while others live in salt water. In the Amphipoda, the body is laterally compressed—as in these shrimps—while in Isopoda it is flattened from top.</td>
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<td><strong>Midges</strong> Chironomidae</td>
<td>Mud and stones at the edge of streams are frequently characterized by seeming &quot;strings&quot; or silt, which may actually be strings of silt-covered algae sheltering small, red &quot;worms.&quot; These may be larvae of some parts in the midges that fly over water at certain seasons, and at various times.</td>
<td>These insects resemble minute mosquitoes, have delicate abdomens, legs and antennae, and are generally smaller. The veins and edges of the wings also lack the frilly fringes characteristic of some parts in mosquitoes. There are more than 200 kinds of midges in North America.</td>
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<td><strong>May Fly</strong> Callibaetis sp.</td>
<td>In 1778, Benjamin Franklin wrote an essay on The Ephemera; An Emblem of Human Life. Errorneously and facetiously, he assumed that May flies, members of the Ephemerida, completed their life history in a day. The insects are delicate, hold wings erect over their backs and bear 2-3 &quot;tails.&quot;</td>
<td>Some 100 species of May flies are known in the United States, and some 500 in the world. They hold their forelegs conspicuously forward, have abdomens that curving upward to rear as adults, and usually functionless mouth parts. Nymphs are aquatic, with abdominal gills and 2-3 &quot;tails.&quot;</td>
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<td><strong>Stone Fly</strong> Perla sp.</td>
<td>Stone flies include more than 3,000 species of insects, mostly residents of waterways that do not become dry. An early species, Capula pygmaea, may appear in dark swarms over snow. Some later species in genus Perla are slow fliers; are sought by trout as food, by men as bait. Nymphs are aquatic.</td>
<td>Some adults are to be found flying over streams, or in abundance on vegetation near streams during the breeding season. The nymphs cling to stones underwater, where they crawl about, seeking animal food. The adults may have non-functional mouth parts, or may have active, chewing mouth parts.</td>
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<tr>
<td><strong>Brook Trout</strong> Salvelinus fontinalis</td>
<td>Tennyson characterizes a brook as having: &quot;...here and there a lusty trout and here and there a grayling. The beauty of a brook trout can hardly be equaled—certainly by nothing whose reftm is the edge of a stream. Weight to 17 pounds. Tail square-tipped. Back with wormlike markings.</td>
<td>Native from Labrador to Georgia, and to Montana and Saskatchewan in waters not exceed six. Now has world-wide distribution, and is becoming popular in farm fishponds. It may be crossed with brown or with lake trout, producing hybrids.</td>
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</table>
Flowers borne in spring on short lateral branches, as catkins whose yellow fruits burst, freeing fluffy seeds. Catkins seem weak, but do not ordinarily droop. White willow may develop freely from August to May. Young larvae are freed into water and become attached to it. They may develop on the larval stage for about 20 days, then leave and in 2 years may develop to 2-inch maturity.

An uninhibited diatom might yield in a year, through its descendants, about 60 tons of material. A bed off the California coast is 1/2-mile thick. In a short time a bed nearly 6 inches thick and to 20 miles long formed off Washington coast. Over 10 million square miles of sea bottom are diatomaceous.

Males free sperms into water. These fertilize the eggs, which lodge in gills of fishes. They may develop freely from August to May. Young larvae are freed into water and become attached to it. They may develop on the larval stage for about 20 days, then leave and in 2 years may develop to 2-inch maturity.

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In one species of midge, the female lays a mass of some 700 brown eggs in water. In 3-4 days, these hatch into larvae that feed on microorganisms in the water. Young larvae are fertilized by swarms of 200-300 flies in the water, with one female laying several thousand eggs. Eggs hatch in water into nymphs that crawl about on rocks under water, possibly requiring to 3 years to reach maturity.

Adults live only a short while, mating in flight. Female may lay to 1,000 eggs, dropping them or placing them under water. In 6 weeks to 3 years nymphs hatch from eggs develop through as many as 21 molts to complete a generation. May be molt in adult stage, but no true pupal stage.

Adults mate soon after emerging from nymph stage, which lives in the water. Female may lay to 1,000 eggs, dropping them or placing them under water. In 6 weeks to 3 years nymphs hatch from eggs develop through as many as 21 molts to complete a generation. May be molt in adult stage, but no true pupal stage.

Female builds nest in rille over gravel bed in spring. Nymphs may be 5,000 eggs that mix with gravel; may be guarded to 3 weeks. At 50° F., eggs may hatch in 44 days, reach maturity in 1-2 years. Nymphs may be to 80 per cent fertile. Water temperature most important in survival.

Food is largely small aquatic animals, but may vary. Cladocera, Brachyuran larvae, fish, and crustaceans may be eaten. Nest is usually made of vegetable fiber in clumps or turf and intermixed with sand, gravel, and pebbles. Water temperature most important in survival.

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Role of tree in anchoring soil along banks of streams is widely recognized, and it is a common practice in stream management to plant young shoots into ground along stream bank to establish and anchor soil, and to retard wasteful erosion. The bank is rich in tannin, and is used in tanning.
<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>RANGE AND RELATIONSHIP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Horned Dace</strong>&lt;br&gt;<code>Semotilus atromaculatus</code></td>
<td>Common in small streams from Maine to Wyoming, to New Mexico and Alabama. It is also known as Creek Chub. May be found in brook trout, common suckers and blacknose dace. Usually found in headwaters, streams, or in pools of larger streams reduced by drought. Family Cyprinidae.</td>
</tr>
<tr>
<td><strong>Two-lined Salamander</strong>&lt;br&gt;<code>Eurycea bislineata</code></td>
<td>From New England to Florida and west to Louisiana and Lake Superior; related and similar species extend range slightly. Nine similar species in area. May winter under trash on land, or in deeper water than in summer. Family Plethodontidae. Order Caudata. Class Amphibia.</td>
</tr>
<tr>
<td><strong>Water Ouzel, Dipper</strong>&lt;br&gt;<code>Cinclus mexicanus</code></td>
<td>Breeds from near tree limit in northwestern Alaska to central-western Alberta, and south to southern California and southern New Mexico, with allied race in Mexico and Guatemala. Family mustelidae is closest to that of the weasels—the Troglobytyidae—and to the wren tits, Family Chamaeleidae.</td>
</tr>
<tr>
<td><strong>Belted Kingfisher</strong>&lt;br&gt;<code>Megaceryle alcyon</code></td>
<td>There are 2 subspecies, the eastern and the western, collectively breeding from Alaska to Newfoundland and south to the Mexican and Gulf of Mexico borders. Range extends to northern South America, including British Guiana, Trinidad and Colombia. Has been seen in Europe.</td>
</tr>
<tr>
<td><strong>Phoebe</strong>&lt;br&gt;<code>Sayornis phoebe</code></td>
<td>Breed from Prince Edward Island to central Mackenzie, and south to northeastern New Mexico and the mountains of Georgia and in United States south of 37°, and on to Vera cruz, Mexico. Three species in the genus recognized in the United States. A flyeratcher. Family Tyrannidae.</td>
</tr>
<tr>
<td><strong>Mink</strong>&lt;br&gt;<code>Mustela vison</code></td>
<td>Range through most of North America except extreme North, the Southwest and Mexico, favoring stream banks. May be found some distance from streams but ordinarily cannot be considered as a desert or montaintop animal. Family Mustelidae.</td>
</tr>
<tr>
<td><strong>Beaver</strong>&lt;br&gt;<code>Castor canadensis</code></td>
<td>Originally ranged through Canada and Alaska to Florida and Mexican border. Once nearly wiped out over much of range; now recovering through protection. Family Castoridae; but not in same family as mice and rats, or in same order as rabbits. Not limited to New World, rare in Old.</td>
</tr>
<tr>
<td><strong>Stream Water</strong>&lt;br&gt;<code>Water plus Pollutants, Oxygen and Motion</code></td>
<td>In periods of flood and drought there may be variations in volume of water, its velocity, its turbidity, and its load of foreign matter, with resultant variations in effect on adjacent soils and on associated living things. All these variations leave records of significance, which may be read.</td>
</tr>
<tr>
<td><strong>Stream Beds</strong>&lt;br&gt;<code>Stream Beds Include Fixed Organic and Inorganic Materials</code></td>
<td>Carved stream beds provide variations in water speed and depth, and provide variations like ripples, pools and shallows, which contribute to providing food, shelter, escape, anchorage to the organic part of stream society. Stream fish require variations in depth of water for livelihood.</td>
</tr>
</tbody>
</table>
REPRODUCTION

Males build nests in rifles, removing silt from an area and making a pebble-lined, circular pit, with pebbles upstream. One or more females may mate with male, lay eggs, and leave male to guard them. Young may reach 1½-inch length in 5 months and 4 inches in 2 years.

Elaborate fall courtship ends when male deposits a jelly-like spermatophore that female picks up. In spring lays eggs under swift water. May lay to 30 eggs, each ½-inch in diameter. Hatch in 10 weeks into slender fry. Young reach length of 2 inches in 2 years before transforming into adults.

Nests on ledge in gorge or canyon, close to—or even under—a waterfall; on rocks in midstream, or on beams under bridges. Nest is bulky, roofed, with a side entrance; made of plant materials, with a dry inner nest of fine material. Eggs white, 3-5. Incubation period is about 15 days.

Nest built in a crevice on a glen wall, under a bridge pier, in an old building or other shelter, usually of mud with a grassy or mossy covering. Eggs 3-8, glossy white, incubated by the female; occasionally by male. In North America: brood in South, 2-3.

Males mate with more than one female, February to March, but stay with one until 3-8 young are born in 45-60 days. Young blind to 5 weeks, with a cloak of fur, and leave den at 6-8 weeks. Breed at 1 year and, protected, may live for 10 years or more.

Apparantly pair for life. Breed January-February, and 2-8 young born in 63-128 days. Suck solid food at 1 month. Cease nursing at 6 weeks. Weight to 8 pounds by midsummer. Mature in 2-3 years. Family is usually basis of a colony, with 2-year-olds driven from old home to start anew.

Movement of stream water largely determines nature of associated organisms, so is of extreme value in explaining behavior of stream while others—by streamlining or by individual effort—use moving water to bring them food, remove wastes, and provide variations needed by animals to go through life cycle.

Stream beds may be scoured by flood waters, rejuvenated by moving silts that erode plants from stone surfaces and change entire stream economy. However, stream bed is rarely uniform either vertically or horizontally; with rest, original status may be regained.

ECOLOGY

Feeds mostly on small aquatic animals, taking a fly or a baited hook readily. Often become pests as bait robbers, raiding hooks offered associated game fishes. May support a large number of external parasites. Are eaten readily by larger fishes, and are thus important ecologically.

Food essentially small animals like worms, insects, crustaceans, usually caught by foraging in daylight in water. May be most active and successful in escape behavior, changing quickly from quiescence to active scrambling. Some salamanders of area may be colon bacteria reservoirs.

Food largely aquatic animals like insects and even fish, including black fly larvae, caddis fly larvae gleaned from wet rocks in or under water. Birds can walk or swim through rapidly-flowing water even when the air temperature is under 30° F. below zero. Favors swift water.

Food almost exclusively insects, usually caught on the fly. Careful surveys indicate that nearly all food taken includes insects and other invertebrates harmful to man's interests, such as crickets, grasshoppers, ants, cucumber beetles, ticks, moths, beetles.

Food is muskrats, birds, frogs, snakes, fish; in winter may pursue, catch and kill cottontails on land. Home range of nursing mother is about twenty acres. Males reach larger area. May raid poultry houses, killing more than are eaten. Den is in hollow log or cave in streambank.

The ability of water to dissolve associated substances affects the stream bank, plants growing in it, and frequently wears away rocks selectively, producing variations that cause change in stream direction and velocity. The dissolved materials affect the plants and animals living in stream.

Physical geography tells enchanting stories of river development of stream systems, and of the records they leave behind them when streams change their courses. Streams abandon portions of their courses, join with other streams, and produce interesting new biologic associations.

ECONOMY

Good, hearty bait mummikin and good fish food for the larger game species of their habitat. Flesh of horned dace is edible, but bones are a bit too abundant. Breeding fish can be stripped of eggs successfully, and fish may be reared in breeding ponds to sell as bait for pike and common panfish.

Usually of only minor importance to man, but do serve role of controlling multiplication of small animals of habitat, and to a minor extent of food for some predators of area. Many salamander species haunt stream banks, and are interesting denizens.

Expresses the wild free spirit of water fishing through a canyon more than any other residence of the meeting place of land and water. Its marvelously loud and pleasant song is in keeping with the setting in which the dipper chooses to live. The bird is described well by many writers.

Kingfishers may make changes in our stream banks, and consideration of their general role in nature may make Audubon banded some of these birds and studied their return habits long before bird banding was popular hobby and research technique. Call something like courting call of chickadee; may be confused with latter.

Habit of nesting about old country homes endears them to many Audubon. Banded some of these birds and studied their return habits long before bird banding was popular hobby and research technique. Call something like courting call of chickadee; may be confused with latter.

"His fur is soft and brown and sleek, and twenty trappers worked a week before they gathered skins enough to make your grandma's cloak and muff." Fur, beaver, is of great use to an ever larger area. May raid poultry houses, killing more than are eaten. Den is in hollow log or cave in streambank.

Dams form ponds that collect sediments and form basis of rich agricultural lands. May flood forested areas, and may destroy orchards and timber trees by flooding or by cutting. Pelts are valuable, and formed basis for much of America's original prosperity and early development.

Temperatures of streams vary partly because of color of rocks in stream beds, partly by possible range of temperature of air mixed with the water in a swiftly moving stream. Temperatures determine both oxygen content of many streams and the plant and animal populations to be found in them.

Just as phenomenal developments take place at borders between fields, so the most fruitful areas of a waterway may be the place where it meets confining land, and where the give and take of soil and violence; and other variants, create conditions for a variety of developments.
In the Springtime, the edges of streams draw youngsters as surely and certainly as a horseshoe magnet attracts bits of iron. Indeed, there are towns in this country where the local merchants give certificates to children who agree to stay away from stream banks during the time of spring high water—certificates that are redeemable in ice-cream cones when the danger season has passed. The merchants feel well rewarded in their contribution to preventing spring accidents, which are all too prevalent along the nation's waterways.

For the purpose of the schoolroom, there are three major questions involved in the study of stream edges. First, what happens at the edges of a stream? Secondly, why does it happen? And lastly, what can be done to make it happen? Certain stream bank events take place quickly—perhaps in a matter of a few seconds. Other events are measured in much longer units of time. But the time element concerned in any particular event is not as important as the sequence of its component parts; for study purposes, the question is: what may be expected to happen next? Is there a definite pattern?

A stream of water flowing along a slushy street gutter in spring may offer some significant lessons for youngsters who like to experiment with dams, channels, diversion ditches, and waterfalls. In such miniature streams the movement of slush may be suggestive of the movement of silt in the larger-scale stream or river; and a description of the events that take place may be made by a young student with a reasonable degree of accuracy.

With the help of the suggestions given in the text of this insert, students may learn how to determine the volume of water that passes a given point in a stream during time of flood. They may learn to estimate the speed of a stream by observing the effect of the moving water on earthy units moving along the stream bottom. They may observe that fragments of ice, breaking free from a stream bank, may carry away larger or smaller portions of soil as they move away. The student may notice, too, how the water in a plunge basin below a waterfall tends to widen the stream at that point, and how, as the speed of the stream diminishes, its load of silt or other material drops to the bottom, perhaps to eventually change the course of the stream.

It might be worth while, in this connection, for the student to map the course of a stream of water through a snow dam, and to clarify the resulting graphic description with a series of pictures showing how the stream course changes, and why.

Holes that may occur in the banks or bottoms of streams are always significant, and they may be studied, mapped, and perhaps explained. Young trappers may learn something of the habits of the animals they seek to capture by learning to identify the tracks, trails, and other signs animals leave behind them, such as scraps of gnawed food, droppings, dens, or signs of conflict.

It might also prove interesting to map the side of a stream through a given distance to indicate the location of all observable birds' nests; the usual routes followed by the birds in flying up or downstream; the sites where the birds sing most frequently; and the territories defended by nesting pairs of birds that use the stream bank as a homsite. It should be noted that some species of birds nesting in or along stream banks seem to enjoy the company of other birds of their own kind; while other species are solitary in their habits.

The student may be able to form an opinion as to such differences of habit by observing the extent of the territory each bird visits in its search for food. Involved here is the relative ability of the different bird species to cover considerable distances with ease. A spotted sandpiper, for example, cannot move with the ease of a cliff swallow, and the two have different communal habits. What suggestions for an explanation do these facts suggest?

The great lessons to be derived from a study of stream edges are primarily associated with the gain and loss of soil along margins. However, any study of the stream bank would not be complete without a mention of stream improvement. How may the banks of a stream be improved? How may the production of food plants—and the small animals that feed the larger animals of the stream—be improved? How may the stream be prevented from adding to the silt pollution and flooding problems? Streams are dynamic and changeable—but they may be managed. A start in understanding them must be made at the school level—and it could well prove to be a most enjoyable subject.
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Tycho Brahe modified the heliocentric theory of Nicolaus Copernicus, mistakenly restoring the earth to the center of the universe. Right. Diagrams of both systems are shown as they appear in J. Hevelius’ Selenographia (Dantzic, 1647).

**SKY REPORTER**

**By Simone Daro Gossner**

It would be wrong to assume that the scientists and philosophers of the Middle Ages and the Renaissance had embraced Ptolemaic theories without reservation. Aristotle—whose principles were the backbone of medieval science—had spoken of perfect celestial bodies moving at constant speed along circular orbits centered on the earth. There was a fundamental conflict between such notions and the Ptolemaic concepts of epicycles and eccentrics, in which bodies were assumed to move around the earth at varying speeds in off-center orbits. Die-hard Aristotelians resolved this dilemma, however reluctantly, by considering Ptolemy’s theories as a convenient mathematical hypothesis, suitable for the prediction of celestial phenomena, but without true physical meaning.

By the time these theories gained general acceptance (ca. A.D. 1400), however, they no longer provided the degree of accuracy required by astronomical observations of the period. Skilled modifications at the hand of fifteenth-century astronomers Purbach and Regiomontanus gave them renewed impetus, but a few of the more liberal thinkers soon began to cast about for other means of solving the problem of planetary motions. One of these men was destined to propose a system which, in its day, led to one of the most impassioned scientific controversies of all times.

Niklaus Koperník, who later latinized his name to Nicolaus Copernicus, was born in Torun, Poland, on February 19, 1473. The youngest son of a magistrate, he was orphaned at the age of ten and was adopted by his maternal uncle Lucas Watzenrode who soon thereafter became Bishop of Ermland (Prussia). His uncle’s intention to prepare him for a lay position within the church governed his education. His studies bore the imprint of an era in which the classics had been newly rediscovered and avenues of learning were eagerly followed.

The young Copernicus was schooled in law and medicine as well as mathematics and astronomy. The decisive turn in his career seems to have occurred during his close association, at the University of Bologna, with the Italian astronomer Domenico Maria da Novara. He participate in Novara’s observations and shared his growing dissatisfaction with ancient planetary theories. It is probable that Copernicus began elaborating his new system shortly after his return to Poland in 1506. Although a preliminary version of his treatise was circulated in manuscript form perhaps as early as 1512, he delayed its publication in full form for fear of ecclesiastical censure. Edited by a few trusted friends, De revolutionibus orbium coelestium (The revolutions of celestial bodies) appeared in print in the spring of 1543, while the author lay on his deathbed felled by a stroke in his seventy-first year.

The Copernican theory follows the Aristotelian tradition of circular orbits described at uniform speed, as does the Ptolemaic hypothesis of epicycles and deferent. But its importance to the history of cosmological thought lies in that it rejects the notion of a universe centered on a static earth. The theory supports this heliocentric star with plausible arguments (in contrast to the short-live...
heliocentric theories of the ancient Greeks, which were mere exercises of the imagination).

All planets, including the earth, have deferents centered on the sun. The moon, hitherto classified as a planet, becomes a satellite of the earth. Rotation of the earth is assumed in order to account for the apparent daily motion of the skies. The seasons are explained correctly as resulting from a tilt of the earth’s polar axis. Finally, all planets are placed in their proper sequence (see diagram at left, facing page), and Copernicus was able to determine from observation their relative distances from the sun in terms of the earth’s own distance from that central body.

Pre-Copernican theories assumed that the universe is in act quite small, with all visible stars attached to an outermost sphere scarcely beyond the orbit of Saturn. Having postulated that the sun, rather than the earth, is the center of the universe, Copernicus was forced to give the sphere of the stars a considerably greater radius. Otherwise, the annual motion of the earth around the sun would have resulted in a periodic displacement in the apparent positions of the stars (larger displacements corresponding to shorter distances). Since no such effect had yet been observed, Copernicus had no choice but to expand the size of the universe. Ironically, such displacements are observed with modern instruments—and prove the validity of heliocentric theories—but they are too minute to have been measurable with the equipment of the sixteenth century.

As it were, the size of Copernicus’ sphere of stars was one of the reasons why the Danish astronomer Tycho Brahe (1546–1601) would not accept the new system: he felt that there was no philosophical justification for such an immense void between Saturn and the stars. In addition, Brahe was a fastidious observer, equipped with the most precise instruments then available. He became intensely aware of the remaining inaccuracies in Copernicus’ work and undertook to develop a theory of his own.

The Tychonic system (see diagram at right, opposite page) was a hybrid between the traditional geocentricism of Ptolemy and the new heliocentric approach. The earth is returned to its privileged position at the center of the universe, which may thus be shrink back to a more “logical” size; the sun and moon revolve around the earth, but the remaining planets revolve around the sun, accompanying the latter in its annual motion; the entire universe moves around the earth once every twenty-four hours. With the fine observations, which Brahe accumulated in his lifetime, there is no doubt that he could have developed his system into a working hypothesis far more precise, albeit more artificial, than that of Copernicus. Because of his untimely death, at the age of fifty-four, Brahe’s proposed system remained unfinished.

Whereas Tycho Brahe’s planetary theory was a compromise intended to uphold some Aristotelian principles, his observations of natural phenomena, on the contrary, did much to refute Aristotle’s pronouncements about the nature of celestial bodies. Although novae (stars that suddenly flare up to many times their original brightness, only to fade away gradually) are not uncommon, Brahe’s detection of such a nova in the constellation of Cassiopeia in 1572, was a novelty at that time. He observed it with care and proved its stellar nature, thus providing the first hint that stars are not the immutably perfect objects that Aristotle had believed them to be.

Brahe’s discussion of the bright comet of 1577 proved equally remarkable. Until then, it had been assumed that comets were atmospheric phenomena. But having compared his observations obtained in Denmark with those of a colleague in Prague, Brahe found that the comet had been seen in the same direction at both places. Therefore he concluded that the object was, in fact, much farther away than the moon and was following a path around the sun that carried it beyond the orbit of Venus (as shown in his diagram, which is reproduced below).

Acceptance of the heliocentric theory was hindered by the philosophical climate of the sixteenth and seventeenth centuries. Aristotelians opposed it solely on the ground that Aristotle had taught otherwise. German and French Protestants were averse to it from the start because it conflicted with a literal interpretation of the Scriptures (the reaction in England was more favorable). The Catholic Church was fairly apathetic at first, but its attitude became adamant when the Italian philosopher Giordano Bruno (1548–1600) expanded the ideas of Copernicus and spoke of an unlimited universe with countless inhabited planets. Bruno was burned at the stake: the Edict of 1616 placed De revolutionibus on the Index “until corrected” and barred the teaching of heliocentric theories. Although the ban was not lifted officially until 1822, Copernicus’ heliocentric views nonetheless gained wide acceptance in the scientific world by the end of the seventeenth century.

Observations of the comet of 1577 convinced Brahe that it was in orbit around the sun (from Opera Omnia, 1648).
THE SKY IN APRIL

From the Almanac:

<table>
<thead>
<tr>
<th>Event</th>
<th>Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Moon</td>
<td>April 1, 12:48 a.m., EST</td>
</tr>
<tr>
<td>Last Quarter</td>
<td>April 8, 5:16 a.m., EST</td>
</tr>
<tr>
<td>New Moon</td>
<td>April 15, 12:38 a.m., EST</td>
</tr>
<tr>
<td>First Quarter</td>
<td>April 22, 4:50 p.m., EST</td>
</tr>
<tr>
<td>Full Moon</td>
<td>April 30, 1:41 p.m., EST</td>
</tr>
</tbody>
</table>

For the visual observer:

Mercury should be viewed during the first few days of April if one wants to see it at all in the course of that month. It will be in the morning sky, rising 45 minutes before the sun on April 1, and 30 minutes before on April 15, but lost in the sun's glare by the end of April.

Venus, on the contrary, will be more favorably placed toward the end of April. Still in the evening sky at the beginning of the month, it will set about an hour after the sun on April 1 and may be seen low in the west at sundown for the next few days. It will be in inferior conjunction on April 10 and thus will enter the morning sky on that date. By the end of April, Venus will have brightened to −4.1 magnitude and will be seen rising in the east about an hour before the sun makes its dawn appearance.

Mars, in Gemini, will be about as bright as Pollux. It will be overhead after sunset on April 1 and will set in the northwest at 2:00 a.m. on that date, at 1:30 a.m. on April 15, and at 1:00 a.m. on April 30. The planet will pass south of Castor and Pollux at midmonth.

Jupiter, in Capricornus (−1.3 magnitude), will rise on the southeastern horizon at 3:00 a.m. on April 1, at 2:00 a.m. on April 15, and at 1:15 a.m. on April 30.

Saturn, also in Capricornus (+0.8 magnitude), will remain approximately 6° west of Jupiter, rising about 15 minutes before the latter throughout April.

The Lyrid meteor shower may be expected on April 23. The moon, at first quarter on the preceding day, should not reduce appreciably the number of visible meteors. This shower is somewhat less than spectacular, however, with a predicted rate of 6 per hour (for a single observer).

The signs of the zodiac:

Shortly before 400 B.C., Babylonian astronomers subdivided the ecliptic into twelve identical sections, each spanning 30°, for the purpose of facilitating their mathematical computations. These sections—or signs—were given the name of the zodiacal constellation that they contained. The first (Aries) began at the vernal equinox. In subsequent centuries, the signs of the zodiac were used extensively as a convenient means of describing the position of sun and planets along the ecliptic. As time went on, the slow change in the orientation of the earth's polar axis in space caused a steady displacement of the vernal equinox with respect to the zodiacal constellations. Today, almost 2,400 years after the Babylonians first subdivided the zodiac, this displacement amounts to nearly a whole constellation. The signs, however, have not been renamed, with the confusing result that the constellation of Pisces is in the sign of Aries, and so forth, around the zodiac. To avoid misunderstanding, the use of zodiacal signs has been discontinued in astronomy. Instead, the positions of planets are now given with respect to the constellations in which they appear.

On the preceding pages, Mrs. Gossner offers the fourth in her 1961 series on the growth of cosmological concepts.
MAGNITUDE SCALE
-0.1 and brighter
0.0 to +2.9
+1.0 to +1.9
+2.0 to +2.9
+3.0 to +3.9
+4.0 and fainter

TIMETABLE
April 1
April 15
April 30

10:00 p.m.
9:00 p.m.
8:00 p.m.
(Local Standard Time)
BLACK-WINGED STILTS, on their long, pink legs, alertly patrol the area around their nest with its speckled eggs. These were found near Lake Atanasovo on the Black Sea coast, as unlike other species, have increased in the last ten years.
A Survey of Bulgarian Birds

Ornithologists make first postwar study of the Balkan area

By Guy Mountfort

Photographs by Eric Hosking

Three great European rivers’ deltas—those of the Rhone in France, the Río Guadalquivir in Spain and the Danube in Bulgaria and Romania—have become centers of great interest to naturalists. All three provide refuge and breeding grounds for some of Europe’s rarest birds, but the pressure of human needs, such as agricultural land reclamation by large-scale drainage projects, is threatening each of them. The animal and plant ecology of the famous Camargue sanctuary in the Rhone Delta has been extensively studied. So, to a lesser degree, has that of the Coto Doñana sanctuary at the mouth of the Guadalquivir. The delta of the Danube, however, has been inaccessible to detailed study for decades and little has been known about its wildlife.

Last year, thanks to the co-operation of the Bulgarian Committee for Cultural Relations with Foreign Countries and of the Academy of Sciences at Sofia, a British expedition of nine leading ornithologists was permitted to make the first postwar exploration of the south bank of the Danube, the adjacent Dobrudja steppe, and the Black Sea coastal regions.

The first task was to locate the Dalmatian pelican and the white pelican—
two species that have long been famous among Bulgaria's birds. In 1868, the combined populations in the delta area were numbered at several million. Today, because of constant persecution by peasant fishermen and the extensive annual cutting or burning of the reed beds in which the great birds nest, the total is no more than 1,000 pairs, of which only 700 breed yearly.

The Dalmatian pelican, the larger bird of the two, represents only a third of these totals, and is obviously in considerable danger of extermination as a European species. Small mixed colonies have been located on the Rumanian side of the Danube, but in Bulgaria only about thirty pairs still nest on Lake Sreburna. When the expedition reached this lake, we were horrified to find that all the nests had just been burned, with young birds in them. Lake Sreburna is listed as a wildlife sanctuary, but enforcement of the law is difficult in such a remote area, and the local peasants have no love of birds that eat fish.

The expedition therefore moved south down the beautiful Black Sea coast in search of the white pelican, 700 of which were eventually located and photographed on Lake Burgas. They were nearly all immature birds
Hundreds of the huge pelicans glide down on stiff wings to inspect the photographer's blind at lake's edge, below.

Black undersurfaces of white pelican's flight feathers, above, distinguish the species from the Dalmatian pelican.
center of a swamp forest. In the course of two weeks, working for one hour each day, we gradually constructed a pylon over forty-five feet high next to the nest-tree, and a hide for the photographer was secured on top.

When all was ready, violent storms turned the region into a quagmire. Next day, though it was still raining, we reached the site, only to find that the newly hatched baby bird had been blown out of the nest! At its forty-five foot fall, it lay on the ground, apparently dying and already flyblown. However, after being warmed inside Eric Hosking's shirt, it was revived and replaced in the nest. Soon both parents returned to feed the chicks and small mammals to the hatching, thus providing a fine series of pictures, the first ever obtained of this handsome species.

Bird life is extremely varied in the Black Sea coastal region. We found great reed warblers nesting colonially around all the lakes, in addition to colonies of various species of ducks, geese, and terns. The strident chorus of warblers' songs vied with the yelping cries of black-winged stilts, which trolled the shallows on grotesque long, pink legs, guarding their spotted eggs on the muddy shores. And the country roads, handsome lek sites of gray shrikes and blue-and-chestnut.

and no nests were found. The flock was too large to be the non-breeding part of the Rumanian bird population, and it seems probable that many must have come from the Russian breeding grounds in the Volga Delta.

The use of poison bait to kill wolves and jackals in Bulgaria has inevitably reduced to a critical level the numbers of carrion-eating birds, such as the bearded vulture and some of the carrion-eating eagles. Fortunately, other large birds of prey are still fairly numerous in remoter regions, and the British expedition was successful in finding and photographing a lesser spotted eagle at its nest. This fine bird occurs only in the Balkans and eastern Europe. The white spots on its dark plumage, from which it gets its name, are visible only in the immature birds. The nest that we located was in the

HEAD-STANDING male great reed warbler feeds his mate as she incubates her eggs in their skillfully suspended nest.

LESSER GRAY SHRIKE, below, resembles loggerhead shrimp of North America, but has a broader mask and a heavier bill.
Mr. Osking has pursued his subjects to all parts of the world. His work has frequently appeared in this magazine.

The expedition specifically sought evidence on the migration of birds along the Black Sea coast. Previously, it had been assumed that spring migrants moved north along the coast and thence either across the Ukraine and to the valleys of the Dniester, Bug, and Dnieper rivers, or westward along the Danube. The expedition found, however, that while huge flocks of migrants occurred in the region of the Black Sea coastal lakes, scarcely any were to be seen north of there. It therefore appeared that, instead of continuing to follow the coast, the flocks turned west across Bulgaria along the southern flank of the great Balkan Range, followed the so-called "Balkan Corridor" valley, and thence moved northwards through Yugoslavia. This view had already been expressed by Mr. Anthony Lambert, the British Minister in Bulgaria, as the result of observations he had made in early spring, but an intensive study must be undertaken to verify the preliminary findings.

Although Bulgaria has as yet no ornithological society and little amateur interest in the subject—indeed, it does not even have any illustrated textbooks on birds—there are indications that vigorous efforts will be made to preserve the exceptionally rich birdlife remaining in the region.
Large frog, huge mouthful for small nestling, is brought to young by a rare lesser spotted eagle in Black Sea swamp forest, above. The bird's name is derived from white sp visible on its dark plumage only when it is still immatura.

Pair of eagles, above, cover on nest in torrential rain. These are the first pictures ever obtained of this species.

Photo blind, right, was built at level of nest, 45 feet above the ground—to which young bird fell and still survive.
Part II

The Decipherment of Linear B

Ancient inventories throw light on Mycenaean everyday life

By JOHN CHADWICK  Illustrations by ENID KOTSCHNIG
Prehistoric Mycenae, reconstructed in these illustrations largely from Minoan materials, had a military system that included coast watchers and messengers to warn of enemies.

The glimpse we have been given of the account books of a long-forgotten people (Natural History, March, 1961) at once raises hopes that through this means we can now gain an insight into life in the Mycenaean age. The reader will recall that three major deposits of these account books have thus far been uncovered: the first at the Palace of Knossos on Crete; the second at Pylos; and the third amid the ruins of Mycenae. Just as the Domesday Book is a vivid social document of life in eleventh-century England, so too the Linear B tablets that the late Michael Ventris first deciphered cast fitful beams of light on the domestic institutions of prehistoric Greece. There is, of course, a vast difference between these two sources, and theories of foreign domination were invoked to account for the precocious brilliance of the Mycenaean at such a remove from the historical Greeks. Even now, two such theories have been put forward: either that the tablets were written by Greek scribes in Greek at the behest of foreign rulers; or that they were written by foreign scribes in Greek for Greek rulers. The best refutation of these theories is the existence in the tablets of large numbers of transparently Greek personal names—and these are not stratified but belong equally to all classes of society. For instance, a person of the highest standing at Pylos is named E-he-ra-wo, which appears to be a well-known type of Greek name Ekhe-lawon; at the other end of the social
too, is Greek—which none but the most determined of enthusiasts will admit.

We know not only that the Mycenaeans were Greeks, but also what sort of Greek they spoke. They were not Dorians, nor apparently Aeolians; it is tempting to call them Achaeans, the name Homer most often uses for the Greeks as a whole. The name Hellenes does not appear until after Homer, and Greek is only taken from the Roman name for the peoples of Greece. What name the Mycenaeans used—if indeed they had one at all—is still a mystery. But at least we can say that linguistically their nearest relatives in the classical period were the Arcadians and Cypriots and, next to them, the Ionians.

What caused the collapse of the Mycenaean civilization is a problem that has intrigued specialists for three-quarters of a century. The decipherment leaves us no nearer a solution. There is reason to believe that the last event in this collapse was an invasion of Dorian Greeks from the wild country of the northwest; but there is no proof that this invasion was the principal cause. Still, assuming that Pylos was expecting the attack, which followed soon after the tablets discovered there were written, we can even read into them references to the forthcoming event.

A number of the Pylos tablets deal with military and naval matters. One small tablet states that a contingent of thirty rowsers, drawn from the coastal villages, is to go to Pleuron. Two other tablets list rowsers, one showing a total of well over 400, some figures being lost; the other mentions “... rowsers who are absent.” We are tempted to speculate: were they absent on duty or absent without leave? Did the navy experience desertion in the face of impending danger? So long as less dramatic explanations are possible, it will be well not to build too ambitious a structure of assumptions on these half-understood phrases.

More significant are a group of tablets dealing with what they call o-la. Despite intensive study, we are still not agreed on the details—in particular on what an o-la was; probably it was a kind of military unit, perhaps a command. The introductory phrase reads: “Thus the watchers are guarding the coastal areas.” It seems clear that the purpose was to establish an observation net, and we may infer from this that an enemy landing from the seas was feared.

Ten “commands” are listed, each belonging to a named man; their location is sometimes given, but not always. Then follows a list of other names, presumably subordinate officers; then the forces at their disposal, often quite small and never larger than 110 men. All the detachments are multiples of ten, so that we may have here a clue to the organization of the army. Each section ends with the entry “... and with them (is) the Follower So-and-So.” The Followers (e-qe-ta = keqatui) are important men—presumably followers of the king and perhaps members of his household, like the counts of German feudal days. Why does each unit have a royal officer, not apparently in charge, but attached? My guess is that he is the communications section. How would the watching units, spread out round a long coast line, make rapid contact with headquarters? Fire signals might be possible for an alarm; but a dispatch rider would be essential, and the Followers, as we know from other
tables, possessed chariots—the fastest means of transport in use at that time. I think that the job of the Follower was to keep the unit in touch with headquarters by means of his chariot.

If this is right we begin to see a picture of the King of Pylos organizing an early warning system; he has a long coast line to defend, and he will not be able to oppose a landing at every point. But, provided he has speedy news of the attack, he may be able to muster his army to meet the invaders. And fight he must, for the palace at Pylos—unlike its counterpart at Mycenae—has no massive walls behind which to shelter. In any event, the preparations proved vain; arrowheads and human bones found outside the palace show that it was defended; but it was burned to the ground, never to be rebuilt.

Although the destruction of the palace at Pylos was violent, we owe to that fire the survival of the clay tablets; for it can hardly be an accident that all three sites that have so far yielded tablets have been destroyed by a violent fire. Yet, of the circumstances of the attack and the fate of the inhabitants we remain ignorant.

Some Cretan place names played an important part in the work of decipherment: about a dozen are now recognizable as known classical sites. Homer speaks of ninety or a hundred cities on the island, but the classical number known is much less. The sites, however, which we believe we can identify with names on the Knossos tablets, cover virtually the whole of Crete, and this seems to imply that Knossos exercised dominion over the whole island. On the other hand, no place names outside Crete can be found, so it would not appear that the Knossos of the fifteenth century B.C. was the center of a maritime empire as suggested by Thucydides; that legend must belong to another era.

Military and naval organization at Knossos cannot be traced, but we do have a certain amount of information about weapons, which enables us to reconstruct some facts about the army. The characteristic weapon of the period was the lightly built, two-horse chariot, carrying two men. Such vehicles were used for peaceful as well as military purposes, if we may judge from scenes in art.

The wheels are inventoried separately, no doubt because they were removed when the vehicle was not in use. Surprising as it may seem to us, Homer knew that the first thing to do on getting your chariot out was to put the wheels on: "Swiftly Hebe put on the chariot the curved wheels, of bronze with eight spokes, about the iron axle." Some of these details do not agree with Mycenaean evidence, though we must make allowances for the fact that Homer is describing a divine chariot. For instance, Mycenean wheels always have four spokes and although one pair at Knossos is described as "of bronze" it is highly doubtful that the whole wheel was made of this material.

The usual wheel material listed on the Knossos tablets is willow or elm, three pairs made of cypress wood are recorded. Tires of some sort seem to have been fitted, and some were both bound with silver. One Knossos tablet mentions as many as 462 pairs.

One series of Knossos tablets undoubtedly is the muster roll of an armored brigade: each tablet records a man's name, a chariot complete with wheels, a cuirass, and a pair of horns. In a few cases there is only a single horse, which may mean that the chariot was not operational. The total is not easily computed, since many of the tablets are fragments; but I count eighty-two chariot ideograms, which gives the minimum figure. We shall probably not be far wrong if we reckon on a chariot force numbering well over a hundred. Each chariot was managed by a driver (a charioteer).
specifically mentioned by one Knossos tablet, but this muster roll contains only one name for each chariot, presumably that of the warrior; the warrior passenger was thus free to fight.

In Homer, chariots seem to be little more than taxicabs, taking the warriors into and out of battle; but this may be, in part at least, owing to the fact that Homer, writing in an age when the chariot had long been obsolete, had forgotten their true use. A formation of a hundred massed chariots charging at a gallop would have been a formidable spectacle; and Homer does appear to recollect such tactics; Nestor advises such a formation, and implies that it is no longer usual. But massed chariots could only have been deployed in open country. In many parts of Greece, the opportunities for such tactics must have been limited, and the chariot force would therefore have been used more as motorized infantry than as tanks.

Unfortunately, the Pylos chariot inventories have not yet been found. Possibly, as at Knossos, they were kept in a separate office outside the main archive room; but they must have existed, for we have plenty of records of wheels. As usual, the scribes were more explicit at Pylos than at Knossos; the wheels are carefully distinguished as serviceable or unserviceable, and some have other epithets, such as "old." A rather surprising feature is the enumeration of wheels as "of the Followers." This implies that the followers of the royal house were in effect the king's chariotry, or at least an important part of it.

The total number of serviceable wheels recorded in the Pylos tablets is in the region of eighty-four pairs; but how many spares were needed for each chariot we do not know. If the roads round Pylos were anything like what they are today, any one pair would not have lasted long.

The body armor worn by the Homeric heroes has been endlessly debated. Efforts have been made to reconcile the descriptions with the archeological evidence, not always with success, and we must allow for anachronisms here as in other parts of the poems. If we study the tablets, the picture becomes a little clearer, for we are lucky enough to have inventories of armor from both Knossos and Pylos that agree in broad outline. The helmet is of a simple, conical shape. We are not told of what material it is made, but leather is a fair guess, for it has attached to it four "plates" or "scales." The word so translated is not identified with an attested Greek word, but the general sense seems clear from its use. How these plates were arranged, or how large they were is not specified, but it may be significant that their number is usually the same at both places, although one Knossos tablet mentions only two plates. Checkpieces must also have been attached to the helmet.

The body was protected by a corselet or cuirass. Again, the material is not specified, but one tablet hints at linen. Attached to this cuirass were some thirty or more plates (again the same word), twenty large and ten small, or in some cases twenty-two large and twelve small. These figures on cuirass plates are from Pylos: relative parts of Knossos tablets are lost.

The weapons carried by the charioters were their spears; wooden shafts, tipped with bronze points. At Pylos, bronze is requisitioned to make "points for spears and arrows." Swords are shown on tablets at Knossos—called by their Homeric name, phasagana—of the broad, two-edged type well known archeologically. There is a slight difficulty here, since the type of sword shown by the tablets is not otherwise known until a slightly later period. Pylos adds the classical word for sword, xiphos, but this would appear to be rather a thin rapier, to judge by the way it is drawn. Arrows are several times mentioned, and a labeled box

were used primarily as draft animals. Chores included olive gathering, weighing the grain, and making cheese and bread.
of arrowheads was found at Knossos; one tablet there gives two totals of 6,010 and 2,630 arrows.

There are two curious gaps in our picture of Mycenaean armor. First, there are no greaves, although “well-greaved” is a favorite Homeric epithet of the Achaeans (and, once, “bronze-greaved”), and the archeologists have recovered them at least from contemporary Cyprus. Secondly, and much more surprisingly, there are no shields. This is an extraordinary omission from the records; we must hope it will eventually be made good, for shields they must have had, and the figure-of-eight shield of early Mycenaean times remained a favorite decorative motif in art.

We know virtually nothing about Mycenaean military organization beyond what has been said above. But a few details of the political and social structure can be picked out amid the general obscurity. Both Knossos and Pylos were monarchies, for both places mention the king (wanax) without any further qualification, which must mean that there was only one king although there is the added complication that the same title seems to have been applied to gods as well. The conclusion that the kingdoms were monarchies, governed by a highly organized bureaucracy, may also be drawn from the complex palaces that have been found. This fact justifies us in extending the deductions from the Knossos and Pylos tablets to Mycenae as well, where the tablets do not provide a direct evidence for the social structure.

There is also an important official called the Lwagetas, or “Leader of the Host,” who seems to rank next to the king. I wondered at first if he might be a title for the heir apparent, but Palmer, pointing to the etymological meaning, has suggested that he more likely is a Commander-in-Chief, and so it is. The king and the queen are the only two people who have a household including tradesmen; just as we meet “the king’s fuller,” so we meet “the shepherd of the Lwagetas.” These two also share the honor of a temenos, the royal holding in Homer, which in late Greek has religious associations. The whole question of land tenure is still hotly disputed. Despite a wealth of documents at Pylos, the exact mea...
ork of men. Weaving was a woman's occupation, although appears that tailoring was done by men as well as women.

ng of the constantly repeated formula remains obscure; and almost the hole of the Pyllos tablets dealing with his subject relate to one village, which may not be typical. Since there the majority of landholders have religious titles, it may be an unusual settlement. The scheme of land tenure here can be worked out in some detail, but what lies behind the bald facts is still a matter of conjecture. Land is divided into types: ke-ke-me-na, which is held from the community (demos), and by therefore mean something like "common"; and ki-ti-me-na = ktume-

ary, which is in the hands of individuals apparently teletai), and etymologically means something like "claimed from the wild," "established"—thus perhaps "private." The large landholders yield a portion of their ktimen to "tenants"; but it must not be supposed that this word implies an actual lease and the payment of rent; we are still far from understanding what economists call the circulation. At the lower end of the social scale we find the slaves. How far society as founded upon slave labor we cannot tell, nor do we know if slaves possessed any rights. An elaborate index from Pyllos records over 600 women, together with about the same number of children. That they are slaves is clear from a variety of indications; some are specifically called "captive" and many are assigned to menial work (grinding corn, carrying water, spinning, and so on). They are not all concentrated in the Palace, but are allocated to other places as well, possibly country houses of the royal family, since their rations are issued by the Palace. But even more interesting than their occupations are the descriptions that betray their origin. Three such epithets clearly relate to places on the eastern side of the Aegean: Lemnos, Knidos, and Miletus. The last of these brings us into contact with the Hittite records, for we know that the king of Abhijawa, who seems to have been a Greek, controlled a place on the Asiatic coast with a name like Miletus. So these places may be Mycenaean colonies or outlying possessions that traded in slaves. Alternatively, we may conjecture that they are the product of piratical raids on a hostile coast, and that the ships of Pyllos ranged far and wide across the Aegean.

Many of the tablets describe men or women by their occupations, and this enables us to form some idea of the complexity of urban life and the specialization of labor. Spinning of yarn and weaving of cloth are women's occupations: carders, spinners, and weavers are specifically named, as well as flax and wool workers. Sewing, however, appears to be done by men as well as women; we find tailors as well as seamstresses. The cleaning of garments is the task of a fuller; the king has his private fuller. A variety of manufactures can be deduced from these occupational terms: carpenters and masons are constructional workers whom we should expect to find; ships are built by a special class of shipwrights, and calekers possibly have their separate trade. Weapons and other metal goods are made by bronzesmiths. Bronze is, of course, still the chief metal in use, articles of iron being very rare and never mentioned in the tablets. Lead is mentioned once at Knossos.

The precious metals include gold, worked by goldsmiths, and used for some vessels and for inlay on furniture. If we look at the actual finds, we shall observe that the goldsmiths also made jewelry; the craftsmanship and artistry of known Mycenaean gold work is of the highest order. Silver, which is not uncommon among the archeological finds, occurs only once on the tablets—a fact that has made us suspect it is sometimes mentioned under another name. The existence of bow-makers is a typical example of the degree of specialization prevailing. The luxury trade is evidenced again by the existence of unguent-boilers or, as we should call them now, perfumers. A number of tablets enable us to see a little of the perfumers' work; they were issued with olive oil as the base, and this was boiled with aromatic substances to make perfumed oil and unguents. We can list three perfumes: rose, Cypersus, and sage. The use of these perfumes is somewhat unexpected; they were sent to the shrines as religious offerings. Whether the Mycenaean ladies also used them we are not told in the tablets, but the numerous perfume flasks found in
women's graves tell their own story. One mention guarantees the existence at Pylos of a physician; unfortunately, we know nothing of his methods or status, except that he appears to have received a grant of land.

Agricultural organization is more simple: shepherds, goatherds, and cowherds show what were the principal domestic animals. In Crete, a vast archive of records bears witness to the immense scale of sheep farming, still an important industry there today. Oxen are much less numerous, and seem to have been used mainly as draft animals; they are sometimes called "workers." It is fascinating to see the names given to a few yoke of oxen: Dapple and Darkie, Whitefoot and Winey. Blondie and Bawler are rough equivalents. A reference to the class of men called "yokers" may mean ox-drivers who attended a yoke of oxen.

Pigs were kept; we have a list of twenty-five, which were being fattened at villages in the kingdom of Pylos. A few tablets mention deer; these are presumably the carcasses of wild animals. Dogs were used for hunting, if we may trust the word for huntsmen (kunagetai), which is, etymologically, "dog-leaders." Horses are rarely mentioned except in connection with chariots; asses are listed only a single time.

The staple item of food was doubtless grain, of which two kinds, probably wheat and barley, are recorded by means of ideograms. It was measured out and ground by women, but the bakers were men. This bread and porridge diet could be enlivened by spices; coriander is the most frequent, but a list from Mycenae includes also celery, cumin, Cyperus, fennel, mint, pennyroyal, safflower (both flowers and seeds), and sesame. Cheese is among the shrine offerings, and was no doubt eaten on a large scale. Figs are another item of diet; the Pylos slave women's rations surprisingly contain the same quantity of figs as of grain. Olive oil and olives were consumed. Another ideogram is plausibly identified as wine, the existence of which can be deduced from the name of one of the oxen mentioned earlier.

An obvious question, to which there is no obvious answer, is: where did the wealth of these kingdoms come from? Articles like ivory and cumin must have been imported from the East; the copper and tin for bronze were not to be found in Greece. The only goods available for export seem to have been agricultural produce and possibly manufactured goods such as pottery, including re-exports in the form of craftsmen's work. The reconstruction of the economy is a complicated task, in which there are too many unknown factors for it to be more than conjectural. We may possibly have to take into account hidden sources of wealth in the form of various kinds of loot, including captive.

But we do know something of the internal economy of the kingdom. Not only was there no coinage—coins were an invention of the seventh century B.C.—there was apparently a commodity in which values could be expressed. The other ancient civilizations of the Near East valued goods in terms of gold and silver; nothing in the kind has so far appeared on Myc...
Invocation to dead, priestess pours libation as music is played and priests offer cup, calf, and boat to the departed.

Two sets of documents may be selected as typical of these operations. First, the long series of tablets from Knossos recording sheep: the totals for some districts run to several thousand, and one tablet mentions as many as 19,000. The individual entries, each on a separate tablet, follow a general plan: a man's name, apparently the owner or keeper of the flock, leads the tablet. Then we have a note of the district, and another man, who appears to be the responsible official of the Palace or tax-officer; and finally the number of sheep. Sometimes this is simply an entry such as "100 rams"; but more often it is broken up into categories thus: "26 rams, 22 ewes; deficit 50 rams." This means that the total assessed was 100; the first two figures record the payment made, the last the balance due. It is significant that in these cases the total, which is not actually expressed, is almost always a round number, most often 100, but numbers like 50, 150, 200, and 300 are also found. Sundwall, who first noticed this feature, thought that the animals were oxen, not sheep, and that they were hecatombs (hundreds) of sacrificial animals. The numbers involved would have made the Cretans astonishingly pious; we must be content with a less picturesque explanation. The sheep must be tribute, because a census is excluded by the round numbers and the calculated deficit. There is another queer thing about these tablets: rams heavily outnumber ewes, not merely in the deficit, which is ordinarily reckoned in rams, but in the figures of sheep received. This must mean that the keepers picked out the members of the flock least useful for its regeneration. Thus we arrive at the conclusion that these large figures represent only a fraction of the total, and a sheep population running into several hundred thousand must be supposed for the whole of Crete—by no means an improbable figure. We can only speculate on what became of the sheep thus contributed; the altar and the kitchen can hardly have accounted for them all, unless meat was eaten on a much greater scale than in classical Greece. In some cases not only sheep but wool too is recorded.

How great was the part played by religion in everyday life we may conjecture both from the numbers of votive objects that have been recovered by the excavators from some shrines, and from the numerous tablets that deal with offerings. But it is no simple matter to identify the deities. The only ones of which we feel sure are those whose names we recognize as equiva-
lent to classical ones. Associated with them are a host of strange names, which may or may not be divine; the listing of offerings to human representatives of the deity, such as the Knossian wind priestess, is a warning against jumping to conclusions.

The recognizable deities are the familiar names of classical Greece: Zeus and Hera (already coupled), Poseidon, Athena, Athene, Artemis, Paiania is an early form of Paiania, later identified with Apollo. Homer tells us that Odysseus stopped “at Amnissos, where is the cave of Eileithyia.” With this clue, the archeologists were able to locate a cave on the coast of Crete, not far from Knossos, which had been in use as a shrine from Minoan times onward. What then was more natural than to find a tablet at Knossos recording the dispatch of a jar of honey to Eleuthia at Amnissos? Eleuthia is a known form of the name Eileithyia, who was the goddess of childbirth.

At this point we begin to pass from the known to the unknown: the Knossos dedications “to all the gods” are not really intelligible, for such a pantheistic cult was not known before Hellenistic times. The worship of the winds is another unfamiliar, although not unknown, cult. But the most curious divine title is a well-known Greek word: Potnia, “the Mistress,” or, as we would say, Our Lady. Once this title is coupled with Athena in a way that recalls Homer’s use of the word as a title for any goddess, but as a rule the word stands alone or in connection with a place name: “Our Lady of the Labyrinth” is surely the most striking dedication to have been discovered out of Knossos.

The usual view in modern times is that the classical Greek religion is to some extent a coalescence of two distinct beliefs: a group of Olympian or celestial deities (a concept shared by other Indo-European peoples); and a chthonic or earthly group, living in the underworld and dominated by a goddess of fertility known to the classical Greeks as Demeter. We know from Minoan and Mycenaean monuments that a female deity played a prominent part in their religion, and I have therefore suggested identifying Potnia with this figure. No certainty is to be reached in such matters, and we must be careful not to equate Potnia with the classical Demeter. There is, however, a powerful argument in favor of a mother-goddess to be drawn from a tablet discovered at Pylos in 1955, which records an offering of oil to the “Divine Mother,” a title strongly reminiscent of the later “Mother of the Gods.” It can hardly be denied now that a cult of this type was known in Mycenaean Pylos.

The gods are mentioned in one capacity only, as the recipients of offerings. These are sometimes animals, and we can presume a ritual of sacrifice. Poseidon, on one tablet, receives one bull, four rams, quantities of wheat, wine, and honey, fifteen cheeses, some unguent, and two sheepskins. This sounds like the provision for a ceremonial banquet, and an interesting illustration of such a ceremony is to be found on a painted sarcophagus from the Cretan site of Hagia Triada. But the commonest offerings are of olive oil. A series of tablets from Knossos are lists of quantities sent to miscellaneous divinities; but a parallel group was lacking from Pylos until 1955, when Blegen uncovered the oil magazines at the back of the Palace. In these were found large storage jars and a group of tablets recording the distribution of the oil, most of which was perfumed. The recipients are usually Potnia, Poseidon, and the king (who, in this context, may be a god—perhaps on another name for Poseidon). In two cases, the oil is described as “for spreading of couches,” a name for ritual meal offered to the gods well known both in late Greek and in Roman rites. In another case we are told that the perfume was “for the anointing of robes.”

One odd omission from our list of Mycenaean occupations of scribe; here the omission almost certain to be due to our ignorance of the correct word, and the title may underlie one of the untranslated words of this group. W might have expected the classic Greek word graphes to be in use, (grapho) “write” meant original “scratch,” a suitable designation the process of writing on clay. B the Cypriots of classical times preferred another word, alino, meani originally “paint”; and if, as in many things, the conservative Cypriots had retained an old word for we might expect this root in Mycenaean. We do not once meet some n-called aloiphoi, but they may be pai.
or greasers rather than scribes. Akkadian cuneiform tablets frequently bear the name of the scribe who wrote them; but not a single Mycenaean tablet has a signature of this kind. It would appear that the writing on a tablet was not a matter of pride to the scribe; we have no parallel to recus, or at least the name of Ugarit who signs himself master-scribe." Nor apparently was there any need to have the responsible scribe's name as a check against wrong dates. However, modern ingenuity is to some extent triumphed over by tiresome omission of the ancients. A brief has made a thorough study of Mycenaean handwriting, and although full results are not yet published, it already clear that a large number of tablets are represented at each site, as each scribe has his own idiosyncrasies; and to the practiced eye the script is not a problem, the or by the name of the month alone. Six month-names are known at Knossos, two at Pylos; there is no overlap between known sets, one Knossos month-name recurs in classical Arcadia.

By contrast there are several mentions in the tablets of "this year" (toto vetos), "next year" (hateron vetos), and "last year's" (perusinicos). These phrases would be meaningless, unless the tablets were current only for a year. This seems to imply that at the beginning of every year the tablets were scrapped and a new series begun.

But, someone will say, the dates may have been not on the documents themselves, but on the filing cabinets. There is an answer to this, too. We know a good deal about the filing system from the excavators' reports. Some tablets were apparently kept in wooden or gypsum boxes, but the majority seem to have been stored in wicker baskets, and when complete the file was marked by a clay label. We have a fair number of these, distinguishable because their back is marked by the pattern of the basketry, where the soft clay was pressed into it. They are in general rather badly preserved, and it was only recently that I thought of checking them according to the tablets they had labeled. A few were obvious; and others could be restored by comparison with the relative tablets; but in no case did the label appear to have borne more than a few words, serving to classify the contents. For instance, the basket containing the corselet tablets was baldly labeled "corselet"; one of those dealing with wheels was more explicit; it read "serviceable wheels for Followers." It is clear that these labels certainly did not contain the missing date.

Another argument also confirms the
absence of old records: the absence of duplicate sets. Every year similar sets of returns must have been compiled; yet with two possible exceptions no duplicate sets have been discovered. Neither of the exceptions is a simple duplicate; one gives additional details, the other appears to be a writing-up, with minor changes, of the information on one set of tablets into a tabulated form. Thus, the records of previous years are clearly absent from our finds; and this means that all the tablets from each site can be safely presumed to have been written within twelve months or very little more. By such a roundabout means we reach the conclusion that writing was by no means rare in the royal palaces.

But how many people outside could read and write? There is a negative piece of evidence that cannot be dismissed on the ground that insufficient sites have been excavated. There is not a single stone-cut inscription known in Linear B; no gravestone bears the name of the dead, no public building the name of the builder. Were it not for the tablets and inscribed jars, we should still think of Mycenaean Greece as illiterate. And this is the more remarkable because Linear A inscriptions have been found on stone and metal objects in Crete.

Lastly, we must deal with a thorny problem: what light do the tablets cast on the Homeric poems? At present there are two schools of thought: those who believe that the Mycenaean element in Homer is great, and those who think it is small. A compromise is here the best solution. We cannot deny that many features of the Homeric world go back to Mycenae.

To take a famous instance, Homer describes a curious kind of helmet made of felt to which are sewn rows of plates cut from boars' tusks. This was an unexplained oddity until a tomb was opened that contained a great number of pieces of boar's tusks, and Wace demonstrated that they could be mounted so as to make just such a helmet as Homer describes. But a helmet of this type can hardly have been known in the eighth century B.C. Its description must have been handed down orally for centuries. If this is true of one detail, why not of others?

Again, consider the queer, archaic language that Homer uses: it must have sounded to the classical Athenians rather as Spenser's Faerie Queene sounds to us. Elements in it clearly come from a Mycenaean source: the case-ending -phi, for example, is unknown in any later dialect, but is common in Mycenaean. All this can be made to add up to a strong case for the preservation of a large Mycenaean element in the epics: in this view, the Trojan War is a historical event and Homer a guide to Mycenaean Greece.

On the other hand, when we compare the tablets with Homer in any detail, discrepancies are immediately obvious. The position of the king may well be the same in both Homer and the tablets: but what has happened to his second in command, the Laogetas? Not only is his name unknown to epic verse, but there is no term that serves instead. So, too, repeatedly with other features: it is all very well to say that Homer was not interested in details of land tenure, but the common Mycenaean term for a plot of land never occurs in the poems.

Several Pylos tablets list, in a consistent order, a group of nine important villages: the coincidence that Homer, in the "Catalogue of Ships," also assigns nine towns to the Pylian kingdom was quickly noted. But the two lists do not match. Homer's includes Pylos; that of the tablets excludes it, and only one of the remaining eight names is the same in both lists. Homer's language contains Mycenaean elements, it is true, but much is of far later date, and the old and new are mixed in such confusion that the attempts of scholars to separate them have produced little agreement or progress. It would seem best neither to exaggerate nor to underestimate the Mycenaean relics in Homer.

Whatever position is finally adopted in this controversy, it is fair to say that Ventris' accomplishment in the decipherment of Linear B has brought an entirely new element into the Homeric problem. It has provided the dumb monuments of prehistoric Greece with a linguistic commentary—incomplete and obscure, but a guarantee that their makers were Greeks. It has pushed back by some seven centuries the date of the earliest Greek inscriptions, and thus given the Greek language a continuous recorded history totaling thirty-three centuries, a record that is rivaled only by Chinese.

Dancers entertain both aristocracy and commoners in open-air amphitheater.
The sum of the wealth that has been won from the mines and quarries of this nation since early days would, in terms of dollars, run into countless billions. Indeed, the sum total can never be more than approximately estimated, since production records of earlier times are often conflicting, inaccurate, or even entirely nonexistent.

In assessing this vast production by national geographic province, we seldom think of our eastern coastal states as substantial contributors to the total, either during past or present times. We are more likely to think of that part of the country as the erstwhile locale of many small and short-lived adventures in iron-making, the hewed stone furnaces for which were fired by charcoal and fed with bog hematite or vein magnetite. We think, too, of this most easterly tier of states as an area peppered since Colonial days with small, sporadically operated and generally uneconomic “prospect holes,” quite often explored at the public expense by way of common—and soon worthless—stock certificates.

Such a casual picture is partly, but not wholly, accurate. It is true that this eastern geographical province—for the present purpose roughly defined as the area between the Atlantic shore and the summit of the Appalachians—has never afforded such phenomenal producers as the “Homestake” of South Dakota’s Black Hills, whose deep shafts have spewed forth some half-billion in gold since 1879; nor has it ever boasted bonanzas like the “Sunshine” mine of Idaho’s Coeur d’Alene mining district, whose quartz veins have yielded as much as twelve million ounces of silver in a single year, making them the world’s second largest producers of this metal.

On the other hand, over the course of the past several hundreds of years, the mineral wealth won in a less spectacular way from the rocks of the eastern seaboard has been very substantial. For example, millions of dollars worth of gold have been taken from a narrow belt of terrain that parallels the east flank of the Appalachians, from Virginia to the rolling, red-earth country of north Georgia. (So productive was this “gold belt” during the earlier part of the past century that branches of the United States Mint were established in Charlotte, North Carolina, and Dahlonega, in north Georgia, for the minting of gold coins.)

A number of copper mining ventures have flourished along or near the coast, from Vermont to Tennessee; a variety of strategic minerals—spar, mica, beryl, asbestos, graphイトen, and others—have been mined and quarried in the eastern states.

Foremost, however, among the important mineral properties of the east on both historically and in point of mind wealth produced, are the twin zinc properties of Ogdensburg and Franklin, New Jersey’s Sussex County, a forty miles from the city of New York. This world-renowned mining- and mineral-collecting locality is near the headwaters of the placid Wallkill River in the highlands of northwestern New Jersey. It lies within a complex assortment of ancient and somber-hued gneis quartzites, and metamorphosed li-
ARK RED ZINCIJE traces a bizarre pattern on its matrix
in the highly crystalline Franklin limestone. This rare mineral
is the oxide of zinc, often carries small amounts of other
elements, and usually occurs as grains or compact masses.

ARK RED ZINCIJE traces a bizarre pattern on its matrix
in the highly crystalline Franklin limestone. This rare mineral
is the oxide of zinc, often carries small amounts of other
elements, and usually occurs as grains or compact masses.
Franklinite is one of the primary minerals of the Sterling Hill and Franklin ore bodies. It is an oxide of iron, zinc, and manganese, and this striking specimen clearly exhibits the mineral's usual octahedral pattern of crystallization.

The matrix of crystalline calcite. It varies considerably in color, even in the same specimen, and may range from colorless through various pastel shades of green, and from pale buff and pale peach through shades of red and reddish brown. Willemite is nearly as hard as franklinite (5.5 on the Mohs scale) but hardly as heavy (specific gravity, 3.9 to 4.2, depending largely on the percentage replacement of the zinc component by manganese and possibly small percentages of iron and other elements).

The third, and by far the least common of the three major zinc ores of Franklin and Ogdensburg, is the rare mineral zincite, occurring as grains and "stringers" in mixtures of the first two minerals. Ordinarily an eye-catching blood-red in color—perhaps through contamination with manganese oxide or some other metallic oxide, since pure zinc oxide is white—zincite is the softest of the three principal minerals (Mohs scale 4), and has a specific gravity of about 5.5. The distribution of the three minerals at both mines has averaged, over the years, about 40 per cent franklinite, 23 per cent willemite, and less than 1 per cent zincite, the remaining material representing the silicates and carbonates of the gangue.

However, it is from this "remaining material," worthless and expensive to the mine operator, that a host of minerals has come to make the twin localities of Franklin and Ogdensburg bywords in the world of mineralogy. For most mineral collectors, these rarities must remain only names in the textbooks of mineralogy—names like rochlingite, barylite, nasonite, sarkinite, yeatmanite, and scores of others, mostly representing unusual or unique combinations of elements like arsenic, lead, barium, boron, beryllium, chlorine, or antimony with the silicate and carbonate components of the locality. Many mineral specimens from these two mines are awaiting professional investigation in their complex chemistry, and are as yet unclassified and nameless.

The exact discovery dates of the 15 properties, rich historically as well mineralogically, have been lost in the haze of the intervening years. There is no evidence that the ore outcropping at Sterling Hill were noticed by the early colonists, but that the name of Franklin was known before 1772. (As a matter of interest, there is an early account that the early colonists of America were just as avid in their quest for mineral wealth as the gold-uranium-seekers of later times.)

Early records show that the first mining operations in the vicinity were primarily directed toward iron deposits, and, since franklinite closely resembles magnetite (the common oxide of iron), it is quite likely that the iron-foundi-
the viciny tried to use it in conjunc-
tion with local and other ores. Ac-
tually it was not until the spring of 1819
at the true identity of franklinite was
established by the laboratory of the
royal School of Mines in Paris. A paper
Lardner Vanuxem and William Keat-
y, read before the Academy of Natural
Sciences in Philadelphia in 1822, at-
tested to the misidentification of these
differing ores in the iron furnaces of Franklin.
"Having long attempted to work by
the common process," noted the two
distinguished American men of science, "an
intoxication which was of a distinct nature, and
rich, consequently, required a distinct
treatment, they (the iron-
kers) at last threw up in disgust an
dertaking which with very little selec-
tion would have been highly productive."
In any case, there was a sheriff's nee-
d of "public vendue," consisting of
the forge situated on a branch of the
skillful (a never ending stream)" and
laves, horses, oxen . . . pig and bar
on, wagons," as well as many other
matters common to early iron-founding.
It remained for one Samuel Fowler, a
actor of medicine and long-time resi-
 dent of the village of Franklin, to put the
ore deposits of the locality to a practical
use, even if in a rather modest way. Dr.
Fowler, a member of the United States
House of Representatives from 1833 to
1837, was a practicing physician and
an inquiring mind. He came into
possession of the Mine Hill zinc property
during the first decade of the nineteenth
century, and his name is prominently
associated with early efforts to utilize
the complex zinc ores of Franklin and
the accompanying locality at Ogdensburg.
The year 1830 found Dr. Fowler pro-
cessing a "flour-white powder" from the
ores. He employed as a substitute
the white lead in painting his house, and
is quite possible that this was the first
ever of zinc oxide from an American
mine for such a purpose, Dr. Fowler
began to deeply engrossed in an effort to
treat the treatment of the stubborn zinc
ores on a commercially profitable basis.
During Samuel Fowler's tenure as a
United States Representative Congress passed a
law authorizing the nation's first set of
standard weights and measures for use
in government customs houses. In
1838, the United States Arsenal in Wash-
ington produced the first metallic zinc
 ever made in this country. It came from
"New Jersey red oxide of zinc" furnished
by Dr. Fowler from his Mine Hill prop-
erty. The zinc was then alloyed with
in the necessary brass for the new weights and measures, and
the ore pit from whence came the par-
ticular "red oxide"—now called zincite
—became known in later years as the
"Weights and Measures opening."
Throughout the early years, the im-
numerous small mine properties at
Franklin and Ogdensburg seemed to be
in constant financial and legal difficul-
ties, and many were the failures, the
sherrif's sales, and the court wrangles
over property boundaries. A guarantee
of future litigation might have been read
into the words of an early surveyor's re-
port, in which, with a blissful disregard
for the passing of the years, it was re-
corded in part that Sterling Hill included
"all that parcel of land in the Province
of East Jersey beginning at two ash
shakes marked with three notches, standing
on the west side of Walkill creek . . ."

Samuel Fowler spent years in search
of a practical method of separat-
ing and reducing the intimately mixed
iron, zinc, and manganese ores of Mine
and Sterling Hills. There was a vast for-
tune in base metals awaiting a fortuitous
turn of the lock; but persistent Dr.
Fowler was not to possess the key to
the treasure house. Toward the middle
of the century, Dr. Fowler died, and
control of the properties passed, by way of
Fowler's son, into the hands of a coura-
geous group that titled themselves the
"Sussex Zinc and Copper Mining and
Manufacturing Company."
In 1852, this organization became the
New Jersey Zinc Company, a mining
 corporation still extant; and a few years
later, in 1865, a method was devised for
producing metallic zinc from the refrac-
tory ores, although production was slow
because of the difficulty encountered in
separating the iron-laden franklinite from
the willemite and zincite. Further
experimentation led to the invention, in
1896, of an ore-dressing apparatus
called the Wetherill magnetic separator,
and at last the flood of metallic treasure
 commenced on the grand scale. The total
wealth given up by these two mining
properties, from first to last, is possi-
ble to estimate exactly; but it runs into
the hundreds of millions of dollars.

On February 13, 1961, Richard W. Westwood died in Washington, D. C. This
internationally known nature educator was the former editor of Nature
and a contributing editor of Natural History after the two publications
merged. His loss is deeply felt both by his colleagues and his hosts of readers.
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I'm arriving at a mineralogical estimate of the Franklin and Sterling Hill deposits, the word unique is admissible. At these two localities, the element z1 occurs in great quantities as an oxide, a silicate, rather than as a sulphide; mineralogical situation which, so far as known, is without a counterpart in the world. The geological reason for such an occurrence has yet to be fathomed, despite the painstaking work of some geology's most acute observers.

Nor is there agreement as to the mode of formation of the ores. Some geologists assign a sedimentary origin to them, feeling that they were original deposited at the bottom of a pre-Cambrian sea, along with the limy sediments that were one day to be called the Franklin limestone. Other geologists think the ore bodies as the highly metamorphosed products of magmatic, or molten rock, action; yet others speculate till the ores were deposited by high-temperature waters and gases, deep beneath the earth's surface, in a so-called placer type of ore deposition. An amateur student of geology and minerology, studying the vast accumulation fact, theory, and speculation develop on the subject, will not doubt sympathize with a one-time superintendent of mines at Franklin, who, on being queried about the geological history the ores, replied, with more sincerity than elegance: 'The origin of the ore not so familiar with, as it has been my misfortune to hear... a good many causes for this ore body being at M. Hill; I hardly know which to accept.'

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THE SURINAM TOAD  George Rahl

LIFE IN THE SCUBA ZONE: PART II  Willis E. Pequegnat

MIGRATING CARIBOU  A. W. F. Banfield

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REVIEWS  Paul R. Juliana

SKY REPORTER  Simone Daro Gossne

NATURALISTS’ NOTEBOOK: A GREEN DARNER EMERGES

NATURE AND THE MICROSCOPE  Julian D. Corrington

COVER: A wall carving in the Naqa Lion Temple in the Sudan shows Apedemak, lion god, war god, and sun god of the ancient Meroites, in a pose suggesting Egyptian imagery—his lionine head in profile, torso almost frontal. Thus martial and celestial functions, he is thought to be associated with ironwork as practiced by the Meroites. This view is supported by slag finds at a view of Meroitic sites, visited last summer by Hans Guggenheim, an artist and scholar of anthropology, whose work has appeared often in the pages of this magazine. His illustrated report on Meroitic ironwork and related finds starts on p. 3.

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THE OCEAN OF AIR, by David I. Blumencord. Rutgers University Press, 86.75: 457 pp., illus.

By virtue of gravitational attraction, the planet earth holds to itself a gaseous composition of nitrogen, oxygen, carbon dioxide, water vapor, and numerous trace gases. By weight, most of this gaseous envelope, which we call the atmosphere, is concentrated within a few miles of the earth's surface; at an altitude of approximately 18,000 feet, one-half of the atmosphere lies below, while two-thirds of it lies below the 29,028-foot summit of Mount Everest.

In its daily rotation, the earth intercepts a prodigious amount of radiant energy from the sun. Some of this energy is reflected back to space; a small amount is absorbed by the gaseous envelope itself, and the remainder is absorbed by the surface of the planet. This absorbed energy represents the energy source for the motions of the atmosphere on all scales. The geometry of the earth's annual orbit and the composition of its atmosphere are such that the equatorial regions receive more heat from the sun in the course of a year than they are able to return to space. In polar regions, on the other hand, the earth and atmosphere radiate more heat than they receive. Thus, the atmosphere, in constantly adjusting this energy imbalance, is caused to move and large-scale wind systems result. This circulation of air on a hemispheric scale is called the general circulation of the atmosphere, and it reveals a number of characteristic wind patterns, such as the easterly trade winds that blow with monotonous regularity over the sub-tropics.

Above the first few thousand feet of the earth's atmosphere, the winds become stronger. Over most of the earth—roughly from latitudes 30° north and south to the Equator—the winds above the surface layer and below 30,000 feet are easterly. Above the remainder of the earth, the winds at these altitudes are westerly. Such winds are integral parts of the large-scale weather systems known by various names: extratropical cyclones, hurricanes, anticyclones, monsoons, easterly waves, and so on. These weather systems are of turbulence—large-scale eddies in the planetary circulation of the atmosphere. Thus, the easterlies and the westerlies lying above the surface layers exhibit large, wavelike oscillations that force the winds to deviate on a daily, weekly, or monthly basis from their usual course. The usual behavior of these systems accounts for the climate of a particular area: the large anticyclones of the tropics, for instance, produce the arid regions of the earth, while "roaring forties" (or middle latitudes) are influenced by the extratropical cyclones of the westerlies, which produce an invigorating climate of large-scale temperature changes and generally above-normal moisture. It is in this belt that most of the earth's humans reside.

Amidst—or, rather, at the bottom—these planetary winds, man works at the power, the complexity, and vagaries of the atmosphere's behavior. A host of terrifying or beautiful, official or disastrous, expected or unexpected events take place as occurrences within these broad-scale wind circulations. Clouds, precipitation, drought, hurricanes, tornados, storms, floods, and so on are all phenomena — collectively, "the weather"—also part of atmospheric phenomena. Such things as auroras, meteors, the transmission of radio waves beyond the horizon, the fluctuations of the earth's magnetic field, the blue of a cloudless sky—all many other invisible phenomena are less familiar to the non-scientist.

Any successful attempt to write a comprehensive survey of the atmosphere, including all its phenomena and its structure and its effects on man, would be an accomplishment in itself. David Blumenstock has written a lengthy book, whose subject, more particularly, is this ocean of air. The physical order, its observation and comprehension to prediction, and its relationship to man. Of necessity, some subject-matter is omitted or touched upon only lightly—mainly the immense field impossible to cover in a treatment. The Ocean of Air is, however, a comprehensive, non-technical survey of the atmosphere, which will be of interest everyone, including the professional meteorologist.

Blumenstock's emphasis is heavy on weather and climate in relation to human activities, and on the economic and historic aspects of the atmosphere immediately enveloping us—the troposphere.
The portion wherein man has lived, raised food, fought battles, and built civilizations, and where the weather that influences all his activities occurs. The author, however, included material on the upper atmosphere—that region above the level of five to ten miles' altitude where weather as we usually think it does not occur, but where we do find such phenomena as auroras, meteorites, and magnetic storms. Even the outermost reaches of the earth's gaseous envelope receive mention: the Van Allen radiation belts and the playgrounds of cosmic rays.

Because until recently, no real science of the lower atmosphere existed and no observational data were to be had from this portion of the atmosphere above this lower portion, the interest was shown in the upper reaches of the atmosphere aside from philosophical speculation. Today, with the emphasis on high-altitude aircraft, space technology, and nuclear weapon testing, these regions above the troposphere are receiving intensive scientific investigation. The modern science of the atmosphere must be said to include the study of these regions and phenomena as well as the processes of the troposphere, which lies below them.

But here we encounter a confusion of definitions. By virtue of long, historical usage, the science of the entire atmosphere is called meteorology. However, it now seems that more clear-cut definitions are needed because of the many almost independent disciplines studying various portions and phenomena of the atmosphere. Geomagneticians, ionospheric physicists, and even aeronomers—a term applied to students of the very high atmosphere, where processes resulting from absorbed solar radiation are dominant—each of these, and many more, is generally conceded his separate discipline.

As a complicating factor, there has been a tendency, deplored by many atmospheric scientists, to divorce physics from weather forecasting. There are, for example, some authorities in such fields as the physics of precipitation or the physics of atmospheric electricity who consider a meteorologist to be a mere weather forecaster, and who consequently do not consider themselves to be meteorologists.

Just what the term "meteorologist" is supposed to mean today is somewhat cloudy, if such a timid pun may be allowed. Perhaps the term should be reserved for students of the general circulation of the portion of the atmosphere, that produces weather, as well as of the prediction of the general circulation and weather-producing mechanisms. Blumenstock's topic, at any rate, is meteorology in this sense, together with the long-term integration of weather processes known as climatology.

A part of all this semantic confusion is due to the historical development of a technology of weather forecasting. Such a technology was the result of overwhelming demands by society for practical results from a science that was still young, but which could make useful
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short-range forecasts on the basis of quasi-scientific rules of thumb and could also make useful studies of aggregates of observed, historical data. Today, a large segment of the public confines the technology with the science, and many atmospheric physicists are unfairly subjected to frequent, tired jests concerning future weather conditions and their inability to foretell them.

Now, the science of the atmosphere as it is concerned with weather forecasting is a unique science. It does not concern itself with scientific inventions, or with the control of natural phenomena, but with prediction. In few other sciences are future conditions the primary concern of the popular interest. Indeed, weather forecasting—as practiced—can hardly be called an exact science. As Blumenstock points out, experience, temperament, an ability to weigh many subjective factors simultaneously, and even, apparently, intuition are all attributes of a good weather forecaster. In my opinion, the dependence on such men has made forecasters partially a science, or art, rather than a science. Such an approach was and is essentially a sterile one: no efficient method can be developed to accumulate, transmit, and digest, in a short period of time, the vast body of technical information acquired by experience and applied by intuition. Thus, for example, college graduates in meteorology, despite their having had the benefit of a scientific education, are of limited use as forecasters.

It is regrettable that Blumenstock did not choose to follow this matter further than he has, since it involves some questions of very general import, as well as some of the most interesting current problems in forecasting. Since the early pioneers in meteorology began studying the physical processes by which the atmosphere gains, transforms, and loses energy, and describing the manner in which the actual behavior of the atmosphere depends on the conditions of energy and water, the atmosphere has been studied as a system of interacting processes, not as a series of isolated phenomena. In the last ten years or so, numerical computers have made possible a rapid advance in techniques of prediction by means of mathematical equations; these are formulated so as to describe "model" atmospheres, resembling the actual atmosphere to greater or lesser degrees. Success with these techniques—to which Blumenstock devotes only a page—has been encouraging; already, the forecasts have led to those made by the method of experience and intuition. But it is obvious that these forecasts are not yet accurate enough to predict the future accurately beyond a month or so, the model atmosphere must resemble the true atmosphere more closely than it now does. For this, for instance, we know the effects of extraterrestrial influences, and we need to take into account the circulation of the oceans, a factor complementary to the atmosphere.

But, even if it were possible to spay all the variables known or thought to have effects on the circulation of the atmosphere, could we then predict, with a weather year in advance with sufficient accuracy to satisfy the farmer, the electrical utilities companies, the airlines, and the housewife? Is the atmosphere, other words, a deterministic system, capable of being described in detail for one month or months in advance?

There is no doubt that the atmosphere obeys physical laws, but the que, raised by the present "plateau of indeterminacy," in many weather forecasts, is whether man will ever be able to cope with the complexity of physical laws and the immense number of observations we need if we are to have these laws to predict future states of the atmosphere accurately. To the agriculturist, farmer, foreman, agriculture, commerce, and industry is a fundamental question, and it is difficult to consider both by the public, as consumers of weather forecasts, and by the scientists, who must decide what factors are of most fruitful lines of research.

Today, the Weather Bureau and private meteorological research organizations are experimenting with forecasting by.data based on probability statements issued with a forecast of the general patterns of possible occurrence to the industrial and commercial user of weather information. The general public, however, is slow to accept such forecasts.

The author includes some pertinent material bearing on the role of the atmosphere in man's efforts to meet problems of the future, such as the need for water. For mankind, water is the most important constituent of the atmosphere, and the hydrological cycle, evaporation, precipitation, runoff, and water presents a series of complex natural processes that man has realized, can, and must be made to work for his benefit. Our future needs for water point toward the importance of the precipitator, and the hydrological cycle. The future atmosphere of greater future almost certainly involves the conversion of saline water, and the author himself suggests.

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Smiths of the Sudan

In Meroë, ancient capital of Nubia, iron smelting flourished.

By Hans Guggenheim
Procussion of gons, led by Apodemak, the lion god, is graven on the stone wall of a Lion Temple in the Sudan.

In the eighth century B.C., a fully developed Nubian Kingdom emerged, with a population composed of Libyan invaders, political refugees from Thebes, and local Negro tribes. These people came to be known to history as the "Ethiopians." Their capital was at Napata (map, p. 10), just below the fourth cataract, and Meroë was their main provincial city. Under vigorous leaders, these southerners pushed north to the conquest of Egypt, itself, and established themselves on the throne of the Pharaohs as the Twenty-fifth (or Ethiopian) Dynasty in 712 B.C.

While ruling in Egypt, the Ethiopians began to expand their original capital of Napata, constructing pyramids for their burials and creating there a civilization that, while Egyptianized, was not without a good deal of distinctive local color. By 662 B.C., however, the Assyrians—who had been threatening Egypt for some time—captured Thebes and forced the retreat of the Ethiopians back to Napata.

Sometime between 538 B.C. and 460 B.C., the Ethiopian kings shifted their seat of government from Napata to Meroë. The exact date for the shift has been difficult to establish, for the early rulers at Meroë still continued to be entombed in the sacred burial sites of the earlier capital. The reasons for the transfer of the capital—whatever the date—were complex. Military considerations may have played a part; Meroë was farther removed from the threat of attack from the north. The steady decline of trade with Egypt may have been another factor. Also, the Ethiopians were cattle raisers, as we know from the numerous cattle sacrifices found in their burials. If Pliny is to be trusted, there was probably more verdure round Meroë than in the more arid region of Napata. But if not the actual reason for the original transfer, certainly the most important factor for the subsequent flowering of Meroë must have been the gradual growth of an extensive iron-smelting industry.

Such an occupation would depend not only on available ores (which were present at both Napata and Meroë) but also even more on the existence of hardwood to provide charcoal for fuel. Of this timber there is
still a supply round Meroë—in the form of extensive forests of svolt, a low-growing acacia that covers wide stretches of the landscape, Pliny’s description—in his Natural History—provides a good picture of the region as much of it still is today: “In the vicinity of Meroë, greener herbage begins . . . a certain amount of forest comes into view, and the tracks of rhinoceros and elephant can be seen.”

As ore, on top of the sandstone of the Nubian plains, a surface crust of ferricretes may be found in layers a few inches thick. In the isolated hills of the region, these ferricretes appear as fairly large blocks, with a peculiar surface of glistening black nodules. Ferricretes seem to be caused by the action of small quantities of moisture that have brought iron, from extensive ferruginous deposits underground, to the surface. The iron ore, of an oolitic nature, runs some 70 per cent ferric oxide, equivalent to nearly 50 per cent metallic ore.

Such a combination of available hardwood and easily accessible iron ore seems to have enabled the old, cattle-raising kingdom of Kush to transform itself into a sort of small industrial empire at some time during the first century B.C. By that time, as a large smelting operation sprang up round Meroë, an astonishing change must have come over the Nubian scene. The smoke of the furnaces can be imagined as rising night and day: indeed, one English writer has compared the Meroë of that time to the industrial Birmingham of England’s nineteenth century.

The evidence for all this activity is still visible at Meroë in the form of enormous slag heaps that surround the ruins of the capital. One of these was large enough to have been used as the base for a temple of Apedemak, the lion god. Another slag pile had to be cut through to allow the modern railway line to pass the site; it was found to be solid slag, twelve feet deep. Regarding this first century B.C. Birmingham of the Sudan, three questions exist, all riddles to which we give only speculative answers:

First, how and when did the Egyptians learn to make iron?

Second, what did they fabricate from their finished iron?

Finally, how was the ore worked?

As to the first question, some kind of iron existed in Egypt as back as 3500 B.C. But only meteoric iron was worked at that time: indeed, such iron was later known as biaxpet (marvel from heaven). The thunderbolt was thought to be of iron, so were the bones of the Egyptian storm god, Set. Small knives made of iron have been found at that date “thunderbolt city,” Cetopolis, dating to 2600 B.C. They belonged to a high priest and “openers of the mouth of the dead,” a ritual necessary to enable the dead to eat the food provided for them in the tombs. It was thought that only iron—which came from the heavens—possessed the magical properties required to form this sacred function.

Very few finds of Egyptian dating to the next 1,500 years have been verified and accepted by scholars. They include the following items from the Fourth Dynasty, as well as a piece of metallurgical interest, for example, a Fifth Dynasty date, from Saqqara; a Sixth Dynasty piece from Abusir together with some similarly dated tools from Dashur; and some iron rust from an Abydos, a supposedly Twelfth Dynasty Nubian spearhead (a piece, too good to be true) recovered from modern Nubian spearheads.

By the Eighteenth Dynasty, an ornamental vessel was received as tribute from “Tinay,” an undefined region north of Egypt, by Thutmose III, as letters mention gifts to Amenhotep II, of this same dynasty, from Tinay (a land in Asia Minor); one steel-bladed dagger, a mitten of iron overlaid with gold and two rings of iron. A “sacred eye” of iron mounted on a gold bracelet belonging to the Twenty-second Dynasty, has also been found, as a clumsily made, miniature headdress.

But it has been concluded by Wainwright, (Sudan Notes and Records, Vol. XI) one of the foremost students of Merotic iron, that also as the Twenty-fifth Dynasty—that is to say, the time of arrival of the
Near Eastern knowledge of iron working may have been one of the reasons why Egypt was unable to withstand the pressure of the Assyrians. The Assyrians spoke of the Nile Empire with contempt, and there is no mention of iron in the meticulous records of the booty taken at Memphis and Thebes when the Assyrians finally succeeded in expelling the Ethiopian Dynasty from Egypt.

What then, about a knowledge of iron among the Ethiopians of the 8th century B.C.? In 654 B.C., a new ruler—succeeded power in Egypt, and the Assyrians with the Iranian and Ionian mercenaries sent to him by Cyges, the King of Lydia, who was trying to gain Egypt's friendship against Ninevah. These Persians and Carians were iron-users: Cambyses, trying to re-establish Egyptian hegemony over the lower Euphrates in 539 B.C., led an army of the people (including Phoenicians) to Egypt. The army was far south as Abu Simbel and Beni, where they seem to have settled down. Until 525 B.C., succeeding kings of these mercenary appear to have entered Nubia. It is possible that they may have introduced the Ethiopians to the knowledge of iron tools and weapons, if not to the actual techniques of ironworking.

Till another group of iron-using Persians appears to the Nile were the Persians under Cambyses, who gained control over Egypt in 525 B.C. Although no direct proof of his presence in Egypt has been found, Cambyses' rule is linked in many ways to Nubia. Herodotus says that Cambyses ruled Merot and named it after his mother, Josephine. Diodorus, who was not a reliable historian, claims that Cambyses named the city after his brother; and Strabo says that the king's wife died there. These legends are probably apocryphal, but even at this date, the Ethiopians seem to have been without iron, for Herodotus says: "... their arrows were tipped not with iron, but with sharpened stone; the stone with which they were sharpened like a lance."

No iron has been found in the royal tombs of Napata from the time of the oldest, that of Kashta (730-714 B.C.), down to Harsihof, who ruled from 342-320 B.C. The same is true of the foundation deposits of the temples of Taharka and Shabaka. Indeed, it has been asserted that, in the great days of the Ethiopian Empire, their kings were as much in the Bronze Age as was the whole of Egypt.

It may be concluded that the knowledge of ready-made iron was brought to the Ethiopians by iron-using foreigners from the north. Possibly, some knowledge of iron smelting also diffused southward to Nubia via Egyptian craftsmen who might have learned the secret from the same sources, but it is not at all inconceiv-
Tuyère, a clay pipe, helped provide furnace draft.

Iron arrow point was tanged to fit into wooden shaft.

Meroitic signet ring of iron shows an engraved lion.

Rod for hanging lamp (shown in restoration) is the largest Meroitic iron relic.

Heroic figure, of wood, from Lion Temple at Meroë.

Stone rings, for archers, are another Meroitic find.
of iron slag; at center, a fragment of a clay furnace wall; at right, a portion of a tuyère to which slag still adheres.

It is thus conceivable that the slag heap on which the temple rests at Meroë was built up somewhat deliberately to create a fitting base for this edifice, and that this was accomplished in a relatively short time. Under these circumstances, it is best to date the beginning of the slag heap conservatively at not much in advance of 150 B.C. and no later than 50 B.C.

Our second question was: what did the Ethiopians do with their iron? For all the enormous amount of melting that went on at Meroë, little has been found by which to measure this Sudanese Birmingham's productivity. Because of imperfect methods, the loss of iron in the slag was shocking, even by primitive standards. But it must still be supposed that the kings of Meroë were well-supplied with iron and that when ironworking was first established it probably operated as a royal monopoly, or perhaps a priestly one. It is even conceivable that the ancient kings encouraged a concept of uncleanliness and impurity in connection with ironworking, perhaps to keep the process secret. Many of the superstitions and beliefs about iron found among present-day primitive African societies are at least suggestive in this respect.

No graves of the common people have been found that fall in the early period of the Meroitic Kingdom (538 B.C.). The earliest find of Meroitic iron is part of the holly contested Ferlini treasure, allegedly found in the pyramid of Queen Amanashakete (45 to 15 B.C.). Among the objects purportedly from this pyramid are a pair of shears, a broken chisel, three spoons, and three needles, all iron.

Iron objects, at this time, are mainly confined to cosmetic articles. However, a skeleton dated ca. 25 B.C. bore an iron arrowhead between the shoulder blades (presumably the cause of death). After that date, arrowheads of iron seem to have increased rapidly. In tomb W 122 at Meroë, which is dated A.D. 150 to 300, the Boston-Harvard expeditions of the 1920's found a quiver containing seventy-three iron-tipped arrows.

After that date, all Meroitic cemeteries that have been dug contain iron objects—with arrowheads in the increase—until the second and third centuries A.D., when iron arrowheads suddenly cease. Even in these later years, however, the number of iron-containing graves is still very small in relation to the total number. At the Farras cemetery, only 107 of 613 recorded graves held iron, while at some of the poorer cemeteries, such as Karanog, the ratio was only 68 graves containing iron to 783 excavated.

By the fourth century A.D., however, the rarity of iron seems to have diminished: expendable arrowheads were manufactured in greatly increasing quantities. These, as well
as agricultural implements such as hoes, may easily have served a double function—as objects useful in themselves and also as a medium of exchange—and may have played a part in the not inconsiderable Nubian trade with Egypt. We know no details, however, of how this trade was effected. Through Egypt, there had been considerable contact between Nubia and the Roman world; indeed, Napata was destroyed in 23 B.C. by Gaius Petronius, although Meroë seems not to have been affected by this event. Roman cultural influence led to the creation of strange mixtures of ideas. In the third century A.D. Meroitic tomb W 122 [already mentioned], next to the quiver with the seventy-three arrowheads, was found an oil lamp associated with traces of the largest single piece of Meroitic iron that has been discovered. It was a diagonal rod connecting the bronze head of a bird with a base from which emerges a large acanthus leaf (illustration, p. 12). The oil lamp, itself, was of Meroitic manufacture. These lamps can be linked with a tradition in lamps of funerary character that ranges from Rome through Egypt to the Far East: the bird symbolizes the sun, the tree (in this case represented by the leaf), the “cosmic tree” or “tree of life.” The use of a valuable iron rod in the assembly of the lamp becomes understandable again if we bear in mind the supposedly magical properties of the metal.

To sum up, a sharp discrepancy exists between evidence for major iron production at Meroë and evidence for end-use of the metal. The grave objects found do not begin to account for the supposed industrial output, even though arrowheads are common after 25 B.C. and the value of iron thereafter seems to have decreased. One possible explanation of this gap between presumed output and the finds is that the concept of uncleanness associated with iron may have made iron objects unpopular as grave furnishings for commoners.

Our final question was: how was the iron worked at Meroë? The ore found in that region is, as we have seen, mostly oölitic—with a great many impurities—including silicon, alumina, sulphur, phosphorus, manganese, and carbon. It is suitable for reduction in the sorts of smelters—called bloomeries—that existed at Meroë. To gain metallic iron, it is necessary to reduce the oxide by adding carbon in some form, such as charcoal. The ore is mixed directly with the fuel and the mixture must reach a temperature of some 500°C to allow the oxygen to pass off as carbon dioxide, leaving residual iron. At temperatures of 800° to 900°C, the iron becomes a pasty mass. At 1400°C, cast iron becomes possible; but the latter, although produced occasionally at Meroë, was presumably considered a waste product, since use of cast iron—brittle and unmalleable—was beyond the technological abilities of craftsmen of this period.

At the Meroë slag heap through which the railroad cut, fragments of smelting-furnace have been found. From these, we may see an indication of the shape of Meroitic furnaces. My own research indicates that these ancient fragments could readily be incorporated into the clay furnaces today by the so-called Jur of southern Sudan (photo, p. 18).

The Jur live along the north of the river Jur in the Bahr el Ghazal area. They were once famous for ironwork, which has now all but ceased. They do not use forced o
al they process the iron in two
ages. Their furnace is about six feet
high, with a diameter of two feet. It
stands inside a small, hollowed-out
Four to six openings are made
highly above the ground level. Into
these openings, short clay pipes (or
tuyères) are inserted, each about six
inches in diameter and two feet long.
These tuyères meet almost in the cen-
ter of the furnace and serve both as
draft flues and as fire bars. The fur-
nace is filled first with some sixteen
baskets of charcoal. On top of this are
placed three baskets of bog-iron ore
that has been broken into small
pieces. One such charge takes nearly
a full day for smelting and produces
enough bloom for eight to ten spear-
heads, or two to three hoe blades. The
latter serve as bride-price money. An
enormous amount of slag is produced
in comparison to useful bloom.
We can fairly imagine a similar
design for the iron smelters of Meroë—
an elongated "eggcup," into the top
of which the ore is poured, while the
main body, below, is stacked with
charcoal. Dr. Dunham, one of the ex-
cavators of the Boston-Harvard expe-
ditions to Meroë, has recently been
kind enough to point out the resem-
blance of this eggcup shape to objects
found by these excavators that were
considered to be braziers. These mini-
ature braziers are supplied with holes
at the base that would facilitate a
draft, and they show, further, that the
eggcup form—like that of the smelter
used by contemporary Jur ironwork-
ers—was familiar to the Meroïtes.
Besides smelter-wall fragments,
pieces of tuyères—the draft inlets—
have also been found at Meroë, iden-
tical in size and shape to those used
today by the Jur. These contain bits
of iron slag at one end. It may be that
forced draft, also, was used at Meroë.
Bits of ostrich feather have been

Mr. GUGGENHEIM, the author-artist,
is indebted to Thabit Hassan Thabit,
Republic of the Sudan Commissioner
of Antiquities, for arranging trips
to key sites, and to Dow Dunham,
of the Boston Museum of Fine Arts,
for his advice on Meroitic problems.
found that might be traces of used to force air into the furnace, kilns large enough to accommodate tuyères can operate on natural alone—as among the Jur.

The Jur process gives us an idea of how all this might have looked. At the end of each firing, the furnace wall is broken open and the iron that has formed at the bottom is moved. The moment the lump is extracted, it is quenched with water—a torch is waved over it. This quenching is considered very important by the Jur and is accompanied by prayer. Strabo, in ancient times, considered the quenching the most important factor in the success of the operation; in fact, he classified the end-products of the furnace as classified on the state of the water used.

After the lump of mixed slag and bloom iron has been quenched, the Jur break it up into small pieces, and the second process can begin. A great ceremony, the pieces of iron are placed in a small clay crucible covered with charcoal. A chick is slaughtered and waved over the crucible. Then, two pairs of bellows are used to create a forced draft and bring the bloom iron inside the crucible to a red heat. When the clay of the crucible looks transparent in the red glow, the Jur know that the iron is ready for working up by their smiths.

Egyptian representations from the tomb of Rekhmire at Thebes (fifteenth century B.C.) show that mithraic process of iron ore (as has been suggested) but a second stage—also necessary to refine the bloom iron, the crucible firing, the Jur method essay to refine the bloom iron, the crucible firing, the Jur method essay to refine the bloom iron, the crucible firing, the Jur method essay to refine the bloom iron, the crucible firing, the Jur method essay to refine the bloom iron, the crucible firing, the Jur method essay to refine the bloom iron, the crucible firing, the Jur method essay to refine the bloom iron, the crucible firing, the Jur method essay to refine the bloom iron, the crucible firing, the Jur method essay to refine the bloom iron, the crucible firing, the Jur method essay to refine the bloom iron, the crucible firing, the Jur method essay to refine the bloom iron, the crucible firing, the Jur method essay to refine the bloom iron, the crucible firing, the Jur method essay 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The pyramids at Meroë, above, are tombs of Meroitic kings; flanks of entrance to temple near Naqa. Object in foreground, topped by residue of ironworking, may have been an altar.
The draft could have been provided by workers alternately treading inflated skins, as in the representation from Thebes or pumpkin skin-covered drums, as the Jur do. Both methods are still common in many parts of Negro Africa.

Sometime between A.D. 300 and 340, Meroë came to an end. No iron was worked there, the city was abandoned and the Meroitic Empire ceased. The reason remains unknown. In speculation that may not be entirely idle, one can imagine a large industrial proletariat, risen and Meroë's iron industry, that was intractable. The pressure of such a group, combined with the rising of barbaric tribes such as the Nāia threatening the capital from all sides, may well have proved too much for an aristocracy softened by the luxury of Roman baths and elaborate spas. A situation not unlike that which existed in Rome itself a hundred years later may have prevailed. In any case, in 340 A.D., when the Amite king put up his victory stele at Axum—proclaiming his rule over Ethiopia—he did not even deign to mention Meroë.

Not only are the origins of ironworking at Meroë obscure, but that city's ultimate influence on other African civilizations is still a matter of speculation. It is possible that the Meroitic knowledge of iron metallurgy diffused southward and eastward together with other cultural traits through Nilotic- and Bantu-speaking tribes. It is possible to think that the great Bantu-speaking population explosion of the eighteenth century—which may have owed its success to the knowledge of iron—was still connected with the past glory of the Meroitic Empire. However, it is no means certain that the knowledge of iron entered Negro Africa from Meroë alone. Carthaginian traders may have diffused this metallurgical skill along the West Coast, while Azanian traders touching Snalia, Kenya, and Tanganyika in the East may have provided still another source. Only further research will show whether ancient Meroë was a prime center for the diffusion into Negro Africa of that region's remarkable, albeit primitive, Iron Age skills.

Smith in a leaf hat, left, checks the draft. Tube at base is tuyère.

**Iron hois blades,** attached to wooden shafts carried by Jur, may be used as money or for tilling fields. Soft metal soon wears out when used in latter role.
The Spring Passage

Breeding traditions draw migrant waterfowl to old nest sites

By H. Albert Hochbaum

The early settlers of the prairie states began their agriculture in the heart of North America's finest waterfowl breeding range. The wetlands of Iowa, Minnesota, and the Dakotas were once as lush with sloughs and potholes as were the best of Canada, and probably just as attractive to marsh birds. Local waterfowl, however, made little impression on the residents, who left poor records of the numbers of ducks that nested in the early days. Resident populations always were overshadowed by the massive rush of spring migrants stopping for a while before flying on northward in their vernal passage. It was the same in the prairie provinces of Canada, where there are no records to compare the early numbers of breeding waterfowl with those of today. In Canada, too, it was the spring passage that was most impressive, and the pairs that remain to nest seemed insignificantly few.

The general failure to realize the importance of local breeding populations is because the ducks space themselves rather thinly over their range. Gregarious through much of the year, they separate pair by pair once they have arrived on grounds. In most species an inter-
for other breeding pairs of the
one kind develops. Thus mallards
right sit side by side, pair by pair, in
herdings of thousands on the Illi-
sis River in March, but in April a
North Dakota or a Manitoba slough
accommodates only one pair of mal-
lards at a time. Migrants keep going
other north because, for one reason
least, there is not room to serve
ire pairs locally.

While one mallard pair will not
breed other breeding mallards, it
will live peacefully with a pair of pin-
tails or gadwall, which, however, will
permit the close presence of
ers of their own species. Some
pairs, however, have smaller spatial
requirements—hence a pothole holds
only one pair of mallards and one
pair of pintails also will serve as the
vidence of two or three pairs of
be-winged teal. And the spacing of
heads and some other diving ducks
is not as well defined as in the mal-
lards. But for all kinds, this territo-
rialism means that breeding pairs do
not congregate in flocks.

l student they spread themselves
widely over the landscape. More-
over, since loafing spots are an es-
ential component of waterfowl
territory, large bodies of water that
attract great numbers of migrants are
virtually empty of those breeders that
are confined to the shore lines. Slough
and pothole country, with its many
separate waters and abundant loafing
situations, provides the best pattern
of territorial terrain. It is on such
range, often in the heart of agricul-
ture, that the heaviest breeding den-
sities of ducks are found. Indeed, the
intensely farmed country round Wa-
ubay, South Dakota, held 124 pairs of
breeding ducks per square mile in
1951, while the best counts on the
delta of the Mackenzie River, one of
the finest northern breeding grounds,
showed only 26 ducks per square mile
nesting there that year.

With the growing interest in local
waterfowl, many naturalists in the
more or less settled parts of the
United States and Canada will visit
numerous small marshes and quiet
shore lines this year in the hope of
locating breeding pairs of ducks that
remained on after the main flight con-
tinued north. An isolated pair seen
day after day on the same pond or
loafing bar is a good indication of nest-
ing interest. If subsequent observa-
tions find the drake by himself in the
mornings, chances are good that his
hen is busy at her nest. Another reli-
able clue to breeding, most conspicu-
os in mallard, black duck, and
pintail, is the "three-bird chase." When a pair intrudes upon the breed-
ing territory of another, the resident
drake rises in attack. There results a dashing, spirited pursuit in which the attacking male drives at the intruding female, pressing hard at her very tail. All the while her own mate lags behind or to one side. The flight is seldom of great duration: after several hundred yards, the attacker sets his wings to scale back to his pond, returning to the side of his mate, who rarely joins in the conflict. It is not yet understood why the male pursues the intruding hen rather than her mate, as is the case in most territorial disputes. But this three-bird chase, seen most often in twilight, is evidence of the presence of local breeders.

The male remains on his territory until his mate has completed her clutch. Then—in mallard and pintail, canvasback, redhead, and most other species—he rapidly loses interest, soon departing to join bachelor friends for gathering in advance of the eclipse molt. In some species, however, notably the blue-winged teal and the lesser scaup, drakes may remain faithful long after the hen has started to incubate. Day after day the male waits at his post, his bright plumage gradually being replaced by the drab eclipse until he is but a shabby shadow of his former self. Despite such loyalty, the drake seldom attends the hen once she has appeared with her brood of ducklings.

In the bigger birds the space requirements are much greater. Both whistling and trumpeter swans establish defended territories, which may be over a mile in diameter. The Canada goose shows variable behavior: some individuals defend huge territories, while others may nest in rather close association. The snow goose and blue goose breed in colonies with nests and territories crowded closely together.

Studies with marked individuals show that the female duck comes back in spring to the same place she used the year before. Dr. Lyle K. Sowls followed the homing of ducks at Delta, Manitoba, by color-marking and banding hens at their nests. Each spring nearly every female on a large study area was captured at her nest by means of a simple drop trap. New birds were color-marked and banded, while the return of old individuals was documented by the identification numbers on their leg bands. Sowls captured one shoveler nesting in the same meadow each year for four consecutive seasons, and the annual recovery of many others led him to conclude that female ducks return to their original nesting place each spring for as long as they survive and the area remains suitable. The drake, of course, cannot be so faithful. Pairing takes place on the wintering

Pull on string, left, drops trap on incubating pintail, who will be banded and coded-colored or, if already banded, checked for fidelity of return to site.
In the prairie states, some young mallards and pintails fly on the wing in early June, exploring the region where they were born and learning the details of the home country to which many of them will return to breed the next spring.
grounds in many species, and new matings occur each spring. Thus, a Manitoba male might mate with a Saskatchewan hen and must follow her to her own home range.

Sowls discovered that the first ducks to return in the spring migration were the adults. This, he noted, gives the old birds an advantage in competing for space. Banding studies indicate that young females find their way back to their natal ranges their first spring, but seldom nest in the same patch of cover where they were hatched. Yearlings return to the place of familiarity learned the previous summer, and yet, with stiff competition for territories, they may be obliged to settle down some distance from the exact site of their birth. Pioneering to new nesting areas is probably accomplished by such young birds that are setting up their first nesting localities.

Young ducks never see their father, and their mother leaves them forever when they are ready to fly. The young of the Canada goose, on the other hand, remain with the parents after they are fledged. Young geese, therefore, have little opportunity to explore their surroundings their first summer. They travel south with their parents as a family group and return with the old birds the first spring. Thus, as family traditions are stronger in the geese, breeding populations are more restricted in area. Young Canadas do not breed during their first or second springs, but when the females start nesting in their third year, they settle down near the place where they were born.

The homing of waterfowl to native ranges means that many attractive marshes are passed by as the migrants press on to reach familiar grounds. So it is that when local breeding populations in the United States have been decimated to the point where there are not enough birds to use all existing habitats in spring, the vacant space is not occupied by passage migrants. Spring travelers stop for a while, but eventually move on beyond such untenanted marshes, no matter how attractive. This is most noticeable in species such as the Canada goose, trumpeter swan, which have a breeding tradition. Once the Canada goose was a common breeder in middle western United States, but is now restricted to a few fine goose marshes. Today, but the local breeders have been killed; there are no native remaining with breeding experience in this region. All the migrant common in the Middle West in fall and winter, however, have for destinations when spring arrives. The trumpeter swan has been completely extirpated from Minnesota and other central states, which were once the common home. The geese and the swans not driven out by settlement, many believe. Neither requires a tame situation, and there are a few swans now nesting within of farmsteads in the Peace River Valley of Alberta. All geese and with local experience were killed in the early days, and the two species vanished as breeders. The same is happening with the canvasback redhead ducks. Despite the dra...
migrating and the Dakotas, there still remain some good areas with ideal nesting situations for the two species. Population counts of resident pairs show, however, that there has been a noticeable and steady decline of native ravashack and redheads.

A reverse process may re-establish the waterfowl to burned-out nesting ranges by the simple process of introducing young stock. When flightless juveniles are released in a new area, it becomes their home, and after their first migration southward they return there rather than to their birthplace. Most successful of such plantings have been with the Canada goose. Now there are many small groups to delight local hunters with their music and the aerial pattern of their wings. Some breeding populations have been accomplished on state and Federal waterfowl refuges, but many bands are located in parks or lakes of cities such as Rochester, Minnesota, or Denver, Colorado. The trumpeter swan might be similarly re-established as a breeding bird on suitable situations still remaining within its former homeland in Minnesota and perhaps in other states where it once nested.

The vernal homing of waterfowl and other spring migrants has puzzled man throughout his history. The manner of orientation still is not clear, but various studies including the many successful transplantations of the Canada goose in the United States make one point clear: a duck is not "instinctively" related to the place of its ancestral home. That is to say, there is no genetic tie linking a duck or a goose to its home range. Each individual learns its surroundings and returns to nest at this familiar place. If, as a flightless young bird, it is removed to a location far from its birthplace, this new area becomes its home grounds—the familiar range that it explores in its first flights—from which it migrates in autumn and to which it returns its first spring. Young waterfowl must learn the details of their homes, and the return in spring migration is the result of learned experience.

The immensity of the feat of homing is perhaps overemphasized when, as with an individual hen, we stress the fact that she "pinpointed" back to the exact nesting place used the previous year. After all, to find this precise spot, the hen first located the larger nest site within which she had had some rather wide experience. Moreover, we know from banding studies that females often range beyond the home marsh after the young are reared, thus further broadening the area of familiarity. A homing hen need not aim her long journey toward the exact nest site. She may strike a much wider objective, and once there she travels over familiar ground to her special nesting spot. The breadth of the "target area" in spring migration is further increased by the advantage of the aerial view gained in migration. At 2,000 feet elevation, for instance, the horizon is about 60 miles to either side. A female arriving at this height sees an area of landscape nearly 120 miles across. The distance of recognition may be further increased by outstanding landmarks. When returning to the Delta Marsh, an arriving hen first sees Lake Manitoba, which is 30 miles wide. A mallard with a home range on the west shore might sight the lake 90 miles east of her nest site, once Lake Manitoba was in view, the home marsh would be an easy mark.

Let us remember, however, that landmarks are not the only guides to migrational orientation. By the work
of modern students of bird behavior—notably Dr. G. V. T. Matthews of England and Dr. Gustav Kramer of Germany—we have gained evidence that the sun and perhaps other heavenly bodies help guide birds in their spring journeys homeward. Such solar guidance is not simply in terms of compass direction by which, for instance, the sun serves as a directional cue to man in local travels. The arc of the sun, together with the schedule of its passage across the sky (man and birds perceiving the sun, as Joshua did, in movement relative to the earth), provides reference to the position of a traveler in terms of latitude and longitude. As the bird flies north in spring, the sun’s arc becomes progressively lower, the angle of its ascent and descent more acute. If travel is also across degrees of longitude, as when a flock of canvasback goes northwest from Chesapeake Bay to Minnesota, the sun rises later and sets later as each step of the journey is accomplished. Birds, of course, have no clocks, but their awareness of time—probably from metabolic cues—is extremely sensitive.

The ability to orient to the sun implies that spring migrants need not be familiar with every detail of landscape on the long way home. An awareness of their situation relative to the sun establishes the correct general direction of travel even when the landscape is not familiar. Individuals are not obliged to follow exactly the same routes each season, step by step, and at Delta, Manitoba, annual variations in the volume of spring travelers suggest that sometimes the bulk of the passage bypasses the south end of Lake Manitoba. Nor must we ever forget, as we marvel at the precision of avian orientation that each year countless numbers of birds become lost, some to delight the ornithologist with the sight of a rare stranger, strayed far from its native habitat.

The homeward migration of waterfowl begins as soon as winter weather relinquishes its hold and open water appears in the central United States. In the mass movements of autumn freeze-up, ducks often fly great distances, continuing on through the night and into the next day before making their first stop, which may be at least a thousand miles from the starting place. In spring, however, the passage is generally in shorter steps as the vanguard keeps pace with the slow advance of the thaw. The movement is in definite waves, which are clearly related to the regular flow of high- and low-pressure areas. Little or no migration takes place during high-pressure weather with its sunny skies and cool north winds. During the cloudless nights of a “high” in early spring, the open waters may

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**Weather Map of April 8, 1954—day following Manitoba’s worst blizzard of year—shows a day that brought migrants to northern Great Plains, but delayed migration in the East.**

**Spring Migration in upper Great Plains is usually south or southeast. From Delta, birds splay out north and nesting is now heaviest in south of pothole area (shaded).**
The journeys of these geese, unlike those of ducks, fly southward in company with their parents in the autumn, returning with them to the home marsh the following spring.

The strong high is followed immediately by a low-pressure area, the change of weather and the arrival of migrants is unbelievably swift. For instance, on April 7, 1954, weather in southern Manitoba was dominated by a high centered in northern Saskatchewan. Winds of 20–25 mph from the northwest created the worst blizzard of the year. The snow blew like dust, reducing visibility to 20 to 30 feet, even though the sky was clear and the sun shone brightly all day. The wind dropped by nightfall. Next morning warm southeast winds of 15–20 mph brought an avalanche of migrants of many species, the heaviest passage of that entire spring.

The very nature of the weather often contributes to the shortness of spring travel, even late in April when the thaw is well advanced. The south winds favoring the travelers are warm and moist. When it overrides cold air to the north, rain, snow, or fog results. Birds starting out under ideal conditions may quickly run into a storm bad enough to halt their northward movement. Sometimes the passage barely gets underway before it must stop. Waterfowl at Delta, Manitoba, sometimes leave the marsh in balmy weather that creates fog when the soft winds strike the frozen lake. The birds turn back almost as soon as they have started. Contrary to a common misunderstanding, birds cannot maintain migrational orientation in a fog, and when dense mist settles over the area, travel is halted.

At the onset of spring migration, wildfowl in large numbers move in a standard direction toward their breeding grounds in the distant north.
northern states have been reached, some birds break from the common route and go their own special way. Canvasback, for instance, may have traveled together from Chesapeake Bay to Lake Christina, Minnesota. But from there they are destined to go to different home marshes, some to the sloughs around Mahnomen, Minnesota, some to the Lake Winnipeg marshes, others breaking farther to the northwest for the Delta Marsh or the Minnesota pothole country.

With the breeding range of ducks spread so widely over the prairies and the northland beyond, the pattern of homeward migration must eventually show as many divisions as there are pairs in flight.

It is probably because of the vast numbers of individual destinations that units of migrant flocks of ducks are small by the time they have arrived on the prairie provinces of Canada. At Delta, Manitoba, departing bands seldom number more than a dozen birds together. Their heaviest flight is into the northwest toward the same point of the compass whence the main flights arrived in autumn. Smaller numbers go north or northeast. The main passage of Canada geese is to the north and northeast. Rarely do these birds fly northwest with the main passage of ducks, although it is the direction followed by whistling swans. The massive movement of blue and lesser snow geese is northeast along a line of flight leading to their next rendezvous on James Bay. Probably most birds make decisions on flight direction at the start of a journey, but on April 20, 1952, Mr. J. W. Baldock of Winnipeg saw a flock of Canada geese split in their flight north along the Red River Valley, one group branching off toward Lake Manitoba, the remainder continuing on toward Lake Winnipeg.

On the Canadian prairies the beginning of each migrant journey of ducks is in the late afternoon or early evening. Passage continues through the twilight and sometimes into the dark of night. The short steps of migration may be completed while there is some twilight remaining in the sky, for the sun is past the equinox, and the angle of its descent gives a long afterglow. A duck departing at sundown might travel 150 miles or so before the last light fades from the sky.

During the early spring at Delta, Manitoba, most arrivals are seen in the evening dusk. They are probably birds that started their travel only a short distance to the south. Later in April, however, new birds may be seen coming in during the morning, no doubt having started from distant points the night before. Most mallards, pintails, and other river ducks are paired when they reach their Canadian breeding grounds, and the migrant flocks are distinctly made up of couples. Some canvasback, redhead, and other diving ducks likewise arrive mated, but mostly the composition of their flocks shows an unbalanced sex ratio, with drakes outnumbering hens and none of the females firmly attached to a male.

What happens when ducks return after a winter in the southland to find the home country untenable? What if fire or agriculture has destroyed all the nestling cover or, worse yet, if the water has vanished with drought?

Wildlife managers have long assumed that when a breeding area becomes dry, the ducks native to that place simply shift to a more favorable location, there to set up housekeeping at once. Indeed, the state and Federal waterfowl breeding refuges in the northern central states were established with such an emergency in view; surely these marshes would serve the greatest function as breeding areas for birds displaced during dry years.

The drought of the late 1950's in North Dakota and the prairie provinces was the first massive dryout since intense biological interest in waterfowl habitat was awakened. Refuge managers in North Dakota and Minnesota and biologists on the larger marshes in Manitoba were heartened in June, 1959, by the arrival of many flocks of paired ducks, evidence of a massive late shift. Drakes and hens were together in pairs, still immaculate in bright breeding dress, apparently eager to settle down and nest on new locations. Settle down they did, but before June was finished it was clear that most had lost all urge for nesting that year. They simply sat about in groups of pairs, passing the time of day without attempting to establish a reproductive schedule. Some, perhaps, had started to nest on their home ground but, thwarted by lowering water levels, had departed. Others nested but lost their eggs to predators that were more than usually efficient in the peck-over—for when the sloughs began to dry, farmers either burned much of the surrounding vegetation or plowed it under. After losing their first nest, the birds attempted no nestings. Pond margins continued to rue. Many others may have given up without trying. Once these birds had gathered in flocks again and moved a new range, they have abandoned all productive efforts for the year.

In normal years of good water, migration barely ends in a given region before some waterfowl are on the move again. With the migration having departed from western Minnesota and southern Manitoba by the first week in May, some groups of early breeding mallard drakes already are breaking away from their hens and territory. First they are seen together in twos and threes, then in bands of a dozen or more by mid-May. By late May these flocks of bachelors are drifting away from the scattered breed areas to the larger marshes in a migration that carries some individuals long distances from where they mated. By the middle of June some of these drakes are in eclipse plumage and are flying with the molt of the wing feathers.

In the prairie states some very small mallard and pintail drakes are on the wing by the end of June, exploring the natal range, learning the home country to which they will return to breed during the following spring—that is, which they will return if their lands are still there another spring.

Each year sees fewer marshes in prairie states and provinces, many of the breeding places drained under government subsidy.

This is largely a case of lack of formation. Both administrators believe drainage is the ultimate solution of the problem. And potholes is of minor importance because waterfowl will, time with end, breed somewhere beyond the horizon. Sadly—tragically—this is not so.

In three bird chase, an interloper female is repulsed by a resident male while her mate, left, lags far behind.
α Sphaera Saturni. β Cubus. γ Sphaera Jovis. δ Tetraëdrum. ε Sphaera Martis. ζ Dēcàédron. η Orbis Terrae. θ Ikosaëdrum. ι Sphaera Veneris. κ Octaëdrum. λ Sphae Mercurii. μ Sol. Medium sive centrum immobile. (Comp. Fol. 214.)
Kepler's observations had attained a degree of accuracy never achieved by any of his predecessors. His foremost ambition had been to use these collected observations to prove the validity of the planetary theory he had proposed. Unable to complete this task in his lifetime, he had entrusted it to his assistant, Johannes Kepler, with the expressed hope that the latter might indeed validate the Tycholean system. Ironically, Brahe's observations were destined to provide the foundation for Kepler's momentous theories of planetary motions, and the Tycholean system was buried with its originator.

Kepler was born at Weil der Stadt, in Swabia (Germany), on December 27, 1571. His strict Lutheran upbringing played an important role in his career. During his period, the Catholic and Reformed churches were vying for control of the various German and Austrian communities; more than once, Kepler was forced to abandon both job and home, and to set forth in search of another position and a new patron.

His college years were spent at the University of Tübingen as a student of theology. Even then his unusual attitudes for mathematics and astronomy were encouraged by one of his teachers, the astronomer Maestlin. Although the teaching of Copernican theories was opposed in the church, Maestlin discussed them in private sessions with his pupils. Quick to perceive the advantages of the new system over the traditional Ptolemaic view, the young Kepler sought to assemble all arguments in its favor.

In March 1594, Kepler interrupted his theological studies to accept a post as mathematics teacher at the seminary of Graz (Austria). From then on, his career was to be devoted to the physical sciences, but his methods and his search for scientific truth continued to reflect the deep mysticism of a very religious man.

The Copernican system provided the means of determining the relative distances of the planets from the sun. Kepler, convinced that the divine arrangement of the solar system did not leave those distances to chance, first sought a general law by which they could be explained. His original theory was outlined in an early work published in 1597 and usually referred to as Promenon (Precursor) or Aeristum cosmographicum (Mystery of the Universe)—with abbreviations of its unwieldy title. Naïve though the system may seem now, Kepler thought of it as the revelation of a fundamental truth. It supposes that the orbit of each planet lies on a sphere, and purports to show that these spheres can be alternately inscribed and circumscribed to the five regular solids mentioned in Euclid's geometry (illustration, left).

Kepler's five solids were at first thought by Kepler to provide a clue to the divine arrangement of the planets in their solar system. Each planet's supposed spherical orbit was shown, left, to lie inside one or another regular shape.

Kepler was the first to recognize that his model of the solar system did not agree fully with observations. Those observations to which he had access were of poor quality, however, and the only reliable ones extant—Tycho Brahe's—were jealously guarded by the latter. By a sudden change of fortune, Kepler was banished from Graz shortly thereafter and invited to seek refuge at Brahe's observatory near Prague. At Brahe's death, a year later (1601), Kepler was appointed as his successor, and thereby came into possession of his monumental records of observations.

Kepler chose as one of his first tasks the analysis of the motion of Mars. Mathematical methods in use at that time were extremely crude. The calculus had not yet been invented, but Kepler's ingenuity supplied the stratagems necessary to solve the problem at hand. Whereas Copernicus still placed the centers of planetary orbits at some distance from the sun, metaphysical convictions led Kepler to assume that the sun must be the true center of motion and perhaps the source of the motive force that keeps the planets moving (the first hint of what Newton would eventually call gravitation). Since the distance of a planet from the sun was known to vary along its orbit, Kepler rejected any a priori concept of circular motions, in spite of those he had assumed in the Prodomus.

Noting that Mars moves more slowly when its solar distance (or radius vector) is greater, he showed by laborious calculations that faster speeds are compensated by shorter distances and, conversely, slower speeds are compensated by longer distances, with the result that the radius vector sweeps equal areas in equal times.

After trying to fit various oval shapes to the orbit, which, obviously, could no longer be considered circular, he reached the remarkable conclusion that planetary orbits are ellipses with the sun at one focus. These two laws of motion first appeared in his Astronomia Nova (1609) after four years of delays and financial difficulties.

Kepler's third law, the crowning achievement of his new cosmology, lies hidden in the last part of an extraordinary volume entitled Harmonice Mundi Libri V (The Five Books of World Harmony) published in 1619. Comparing the periods of the planets—that is, the times in which they complete one revolution around the sun—with their mean distances from the sun, he had found that the square of the period increases as the cube of the mean distance.

With the formulation of his third law, Kepler had come almost full circle since the Promenon. Once again, it was his profound mysticism that had led him to seek a mathematical expression that could represent an orderly universe, but in this latter venture, his acquired knowledge of precise planetary motions had served him in good stead. Kepler's third law, as in fact the other two, were to require only slight modifications at the hands of Newton and his successors. After many weary centuries, thanks to Kepler's efforts, the modern era of celestial mechanics had begun.
THE SKY IN MAY

From the Almanac:

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<th>Phase</th>
<th>Date</th>
<th>Time</th>
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<tr>
<td>Last Quarter</td>
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<td>7:10 PM</td>
</tr>
<tr>
<td>New Moon</td>
<td>May 14</td>
<td>11:55 PM</td>
</tr>
<tr>
<td>First Quarter</td>
<td>May 22</td>
<td>11:19 PM</td>
</tr>
<tr>
<td>Full Moon</td>
<td>May 29</td>
<td>11:30 PM</td>
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For the visual observer:

Mercury, in superior conjunction on May 1, will be too close to the sun to be observed in early May. In the evening sky throughout the month, it will be visible near the western horizon after dark during the last half of May. The planet will set an hour and a half after the sun on May 15, and two hours afterward on May 31. It will reach its greatest eastern elongation on May 31.

Venus, in the constellation of Pisces, will rise at about 3:30 A.M., local time, on May 1, at 3:00 A.M. on May 15, and at 2:50 A.M. on May 31. It will attain its greatest brilliancy (−4.2 magnitude) on May 16 and will be very conspicuous in the eastern sky before sunrise.

Mars, in Cancer, will be up in the western sky at dusk and will set in the northwest at 12:30 A.M. on May 1, and at 11:15 P.M. on May 31. Its brightness will fade gradually from +1.3 magnitude on May 1 to +1.6 on May 31.

Jupiter, in Capricornus (−2.0 magnitude), will rise in the southeast at 1:00 A.M. on May 1, at midnight on May 15, and at 11:00 P.M. on May 31. It will be found in the southern sky at the time of sunrise. The planet will be at a stationary point in its apparent orbit on May 25.

Saturn, also in Capricornus (+0.7 magnitude), will be about 7° west of Jupiter during the month of May. Accordingly, this planet will rise in the southeast approximately half an hour before Jupiter over the entire period and will be low in the south at sunrise. Saturn will reach a stationary point in its apparent orbit on May 9.

The Eta Aquarid meteor shower may be expected on May 4, with a maximum rate of 20 meteors per hour (as seen by a single observer). The moon will be gibbous.

Angular distances:

By convention, apparent distances between stars, planets and other celestial bodies are expressed in degrees and fractions thereof. Although their accurate measurement requires precise equipment, it is often useful to be able to gauge these angles approximately.

A great circle on the celestial sphere is equal to 360 degrees by definition; thus the angular distance from the horizon to the zenith is 90° or one-quarter of a circle. On that basis, the two stars forming the pointers of the Big Dipper are approximately 5° apart. For smaller angles, it is convenient to remember that the diameter of the full moon is half a degree (in this case, however, one should not use the moon for comparison when that satellite is close to the horizon, because in that position an optical illusion makes it look much bigger than it is).

The observer’s own hand may be used to advantage for scaling off large distances. If the arm is fully extended toward the sky, with all fingers outstretched, the angle subtended between the tip of the thumb and the tip of the little finger is equal, on the average, to a span of 22°.

On the preceding page, MRS. GOSNER offers the fifth in her 1961 series on the growth of cosmological concepts.
Green darner dragonfly nymph stands poised underwater, above, as it waits for a small fish to come within range. Extraordinarily large, sensitive eyes give the carnivorous dragonfly a considerable advantage in competition for food.

A GREEN DARNER EMERGES

Nymph's labium, or lip, is extended almost faster than the human eye can see to seize the fish, securing it with two sharp hooks, above. The entire fish will be devoured with labium retracts to pull prey into nymph's jagged-tooth jaws.
Many insects do not deserve the common names that humans give them, but the dragonfly—boasting one of the most menacing faces seen in nature—would seem to be aptly labeled. Yet, despite its grotesque facial structure and predatory behavior, the dragonfly should be numbered among mankind's benefactors: it eats large numbers of mosquitoes and other harmful insects, and then is eaten in turn.

The fact is that the dragonfly long ago secured its role in the balance of nature. Giant ancestors of today's dragonflies—some attained wing spans of thirty inches on foot-long bodies—dominated the skies at a time before flying reptiles or birds existed, while fossil remains about the size of today's dragonflies have been found in rock some 260 million years old. Today's descendants include the 5,000 species of the Order Odonata. One of the largest, fastest, and most brilliantly colored is Anax junius, the green darter, familiarly known as the "darning needle." The darning needle is but one of 400 species of dragonflies and damselflies to be found in North America, and although there are numerous variations in the structure, habits, and cycles of these species, all have certain basic similarities.

When seen aloft, the darning needle is actually nearing the end of its life, the greater part of which has been passed as an aquatic insect. The female deposits her eggs in waterweeds below the surface by puncturing holes in the stem with her ovipositor. After about two weeks, the eggs hatch and the second and longest period of the dragonfly's life cycle begins.

This is the nymphal stage, during which the insect dwells on underwater vegetation or sunken logs, feeding on small forms of aquatic life—including other nymphs. As the nymph eats, it grows; and as it grows, it repeatedly bursts its outer skin. Sometimes there are as many as ten molts before the nymph attains full size.

At this stage, a more radical change occurs. The nymph has been breathing by means of an abdominal gill chamber, but now it must put its head and thorax above the water in order to breathe (photo, right). Shortly thereafter, it climbs entirely out of the water to enter its third and final stage.

After aquatic year, the nymph, right, leaves water for rest of its life span.
**STRUGGLE TO SUNLIGHT**

The final transformation from an ugly nymph to a shimmering-winged, brightly colored dragonfly may be witnessed all over North America, especially during the warm months of late spring, by close observation of the vegetation at the edges of ponds and streams. The nymph remains quiescent for hours after emerging from the water, while crucial physiological changes occur within it. Then the nympha! skin splits for the last time. This time, a new head and thorax appear through the upper back. Now begins the "birth struggle"—a series of exertions and contortions as the adult dragonfly fights to extricate itself from its nympha! skin.

As it emerges, its body is seen to be divided into three parts: the long, slender, segmented abdomen; the thorax, to which are attached the legs and wings; and the head. It is this head that has earned the dragonfly its name: it is a bulging configuration, with antennae, oversized compound eyes, and flexible lower lip, or labium, with jagged-tooth jaws just visible. The main pair of eyes, alone, would give the dragonfly an advantage in its brief existence. These huge organs are each composed of as many as 20,000 sight units, while three other single eyes are situated on the upper surface of the head. Together, they allow the dragonfly to see in all directions at once and to detect motion as far as fifty yards away.

The wings of the dragonfly are its most spectacular feature. As they are pumped up, intricate patterns of veins are revealed—patterns sufficiently differentiated to enable us to distinguish and classify the various species. For the adult dragonfly, its wings represent life itself. Rain, wind, or clouds may occasionally drive it to shelter, but otherwise the green darner spends most of its life on the wing—darting and hovering, preying and eluding—the gauzy-winged insect known to us. Finally, the male and female will mate in flight, and after the female has deposited the eggs in some reed at the edge of a pond or stream, the dragonfly's life cycle will start in anew.
It dangles for a while, head down and throbbing, debilitated from exertions.

Emerge, above, as the first stage in the exhausting struggle to extricate self.

Head and thorax of the adult insect are now clearly free of the old skin, above. Note the moist, crumpled wings as they emerge from the old wing cases.

Revivified, the dragonfly now arches its body back to cling to the head of the nymph case, above, for a final effort at freeing last segments of its abdomen.
Exhausted dragonfly rests its damp body, above. As blood circulates, below, wings expand; color changes take place.

Adult green darter spreads out its finely veined, gossamer wings, right, before embarking on a brief aerial existence.
The Surinam Toad

Pipa pipa’s aquatic ballet implants eggs in female’s back

By GEORGE RABB

The life history of our common frogs follows a familiar course. Typically, frogs lay numerous small eggs in ponds or streams. The eggs develop quickly into the large-headed, long-tailed, limbless, aquatic larvae we know as tadpoles or polliwogs. After a growth period that lasts for a few weeks (or even several summers, as occurs with the bullfrog), the tadpole transforms. Practically all the body parts change at this time, and the result is a miniature of the adult frog, equipped for life on land.

Since the defenseless eggs and young are food for many predators, it seems that only by producing great numbers of eggs can most frog species maintain their populations. As with other cold-blooded vertebrate animals, however, there have been trends toward apparently “safer” ways of development among frogs. Thus, the aquatic larval stage has been eliminated or shortened in some species in most of the families of frogs. Each of these departures from the typical mode of frog development seems to have come about independently, and there is thus a variety of approaches to this period of early development to be observed.

Only a few of these odd breeders occur in the northern part of the world. Such a one is the midwife toad, Alytes obstetricans, of southwestern Europe. The male of this terrestrial frog carries the eggs entwined about his legs during their early development. Later, he backs into a pond to release the tadpoles. In southern Florida, the greenhouse frog, Eleutherodactylus ricordi, and in Texas another Eleutherodactylus and two species of the related genus Syrrhopus, lay their eggs on land. The entire development of the young takes place within large-yolked eggs, which may be guarded and perhaps kept in a moist state for one of the parents during the 6 months that precede hatching.

Most of the oddities are found in the Tropics and farther south. Among them are the marsupial tree frog (Gastrotheca) of South America which carry the young in a deep pocket on the mother’s back skin. The young emerge as froglets or tadpoles, depending upon the species. Even more interesting are two species of small African toads (Nectophrynoides) that give birth to fully developed young. The pregnancy resembles that of some viviparous reptiles. Observations are still needed on the fertilization process in these toads. Another fascinating breeding habit is that of Darwin’s frog, Rhinoderma darwinii. The male of this small, brightly colored species of southern South America carries the offspring about in his enlarged vocal pouches!
Perhaps the most widely known of these exotic frogs is the Surinam toad, *Pipa pipa*. Its habit of carrying the young in individual pits on the mother’s back has been written about for more than 250 years, and the general outline of its embryology has been known for nearly a century. This toad is found over a large part of northern South America, from Trinidad and the Guianas to northeastern Peru. It belongs to a primitive family of frogs, *Pipidae*, that has members in Africa as well as South America. In all five South American species (but not in the African form), the female frog carries the eggs on her back. In two of these egg-carrying species, the young emerge as well-developed tadpoles, but in the other three as froglets.
Male toad, above, exhibits temporary fold in belly skin as he presses eggs to female. Fold forms when body arches.

Imbedded eggs on female's back, below, rest near vent. Tumid skin and inflated lung cause swelling at ribs.
ill frogs, sometimes attaining a body length of eight inches and a weight of about one pound. So far as is known, it is wholly aquatic. The large, fully webbed feet and powerful hind leg muscles are well adapted for swimming. Another obvious adaptation for an aquatic existence is the retention of parts of the “lateral line” system—the pressure- and direction-sensing network in the skin of fish and aquatic amphibian larvae. The body itself is very flat and the gape of the toad’s toothless, tongueless mouth is enormous. The animal’s bizarre appearance is enhanced by skin filaments that dangle from beneath the small, lidless eyes and the snout, and also by the larger, loose skin flaps attached to the sides of the head. Even the long fingers are odd: their very sensitive tips are forked into several toes. The color of *P. pipa*’s upper side is usually gray, with darker brownish or blackish blotches. Fairly rapid shifts in color shade are made on occasion, especially when light conditions change. The underside is mostly white, but in many specimens a large, V-shaped, dark marking is noticeable in the chest and the belly.

Reproductive habits of the Surinam toad have long been a mystery despite the fact that the species till breed in captivity. At the Brookfield Zoo two years ago, we received a few specimens captured in a tributary of the Amazon River in Colombia. Since then, one pair has bred twice. The following description is based mainly on observations of this pair.

When a male is in breeding condition, he makes a series of sharp, clicking noises. The sound is not unlike that of a coin tapped on an aquarium wall. In fact, such tapping will often induce a response by a male. Unlike other frogs, which make their breeding calls by vibrating the vocal cords and using throat pouches for amplifying chambers, the male Surinam toad makes his call by “popping” or “slipping” a joint in a bony voice box. The clicking noise carries well through water and the sound probably would attract a mate in the wild.

A female ready to breed will allow
The male to grip her firmly about the lower part of her body. If she is not receptive, she quivers until released. In our aquarium, a male will make mistakes by grasping at freshly fed females, which resemble egg-laden ones in their stoutness. He is soon informed of the actual situation.

If the female is ready, the clasp is maintained for more than a day. During this time, the skin on the female’s back becomes puffy as the blood supply to it is increased. The male occasionally tightens his arms abruptly, perhaps thereby stimulating the release of eggs from the ovary to the oviduct. When egg-laying is near, the pair begins to turn over repeatedly in the water (Illustrations, p. 41). This action, effected mostly by the female, consists of a half-roll and a half-forward somersault. First there is a rising rotation about the long axis of the body, a momentary pause in the resulting inverted position, and then a descending rotation about the transverse axis of the body.

This maneuver was puzzling at first, but the role that it plays became evident when the first egg was laid. The egg popped forth in the middle of a turnover while the pair was upside down in the water! In most productive turnovers, 3 to 5 eggs are laid, and the total number ranges from 40 to more than 200. As the eggs emerge they are more or less caught by the male’s belly and its temporary anterior and posterior folds of skin. As the pair flips over and returns to the bottom, the eggs drop onto the back of the female and adhere there as the male fertilizes them.

The entire turnover process takes only eleven to fourteen seconds, and the expulsion of the eggs must be synchronized with the mid-turnover pause—about one second in duration. Otherwise, the eggs fall to the bottom and are lost. We recorded 20 per cent losses from mistiming. During the upward movement of the turnover, we noted that the male moves his fingers against the belly of the female, perhaps stimulating or helping her to expel the eggs a second later.

The contact of the expelled eggs against the male apparently induces him to relax his grip and emit seminal fluid as the pair descends. When he tightens his clasp of the female again, he usually presses the newly laid eggs more deeply into the skin of her back. The eggs themselves have no sticky quality. When all eggs have been expelled, the female indicates that she has finished by quivering. Then the male releases her.

The development of the eggs—each about a quarter of an inch in diameter—is a slow process. They sink gradually into the skin of the female’s back, becoming flush with its surface on about the tenth day. Some eggs are crowded out and lost during this period. The outermost egg membrane forms a cap for the skin pocket, or cell, in which the egg develops. This cap is soon covered with debris, so that it is difficult to see what is happening to the egg. Even so, eye pigment and ear stones are evident in the end of the second week.

By the middle of the fourth week the embryo is able to move quick within its brood pocket and will do in response to bright light directed at the eyes. Although the young do not go through a tadpole stage, they possess a tail during growth, which probably provides a surface for oxygen exchange with the walls of the pocket, which are richly supplied with blood vessels. The tail is sorbed at least three weeks after young leave the mother’s back place as a probable respiratory organ may be taken both by transparent sue that protrudes temporarily from the vent of the young and by the relatively large skin flaps at the side of the mouth. Judging from dry weights of young and eggs, there does not seem to be any passage of nutrient from the mother to her offspring.

The emergence date for our frogs varied from 77 to 136 days after egg-laying. Emergence seems related in part to skin-shedding by the mother. In both observed breeding some young were lost at the end of the second month, when the mother shed the aborted young at this stage had a great mass of abdominal fat but had resorbed the tail.
Cell caps are often lost in the first shedding, and the young may then put legs, arms, or snouts out of the opening. If the female sheds again, the young are apt to leave; the shed skin of the pocket walls probably hinders oxygen exchange. The mother also has an active role in ridding herself of the young. She exerts internal pressure that forces the young partly from their pouches for a minute or two at a time. Eventually the froglets seem to respond to this and pop out under their own power, to swim to the surface. The newly emerged young are tiny, compared to the adults; they average about three quarters of an inch in length and only a little more than a tenth of an ounce in weight.

The young stay at the surface of the water most of the time for the first month or two after emergence. At first they have difficulty adjusting their buoyance for diving. They feed quickly in a recoil action common to other members of the family: a sweeping grab when food comes close or touches the hands, and an instantaneous backward thrust of the body.

When the young of the first brood poked their heads and legs out of their pockets, we attempted feeding them. They responded vigorously to small, wigglng worms that were dropped onto the mother’s back.

A matter not easy to understand is that the mother does not eat her free-swimming young. Ordinarily, any small, moving object touching a Surinam toad’s fingers is swept into its mouth, but this has not happened to the young Pipa pipa that have so stimulated their mother. We thought this immunity might depend on the female’s sight, and so we removed the young of the first brood from the mother’s aquarium to prevent mistakes during the night. However, the young of the second brood have been left with the mother for more than two months as this article is written, and no harm has come to them. It may be that, in the evolution of the Surinam toad’s odd brooding care, this curb on the mother’s normal feeding behavior was brought about by selection: the mothers who snapped up their young would necessarily leave few offspring compared to mothers who refrained.
Diet and form are the keys to population densities in the shallow, offshore waters

By Willis E. Pequegnat

The nature of the sea bottom exerts an important influence upon the distribution of the benthos—all bottom-dwelling, marine animals. This fact is recognized by a division of all such marine life into two great groups—the epifauna (which inhabit rock and other hard substrata) and the infauna (dwellers on soft, level bottoms). Even though the epifauna occupies only about 10 per cent and the infauna the remaining 90 per cent of the world's sea bottom, roughly more than four times as many epifaunal than infaunal species have been described up to the present.

The competition for space among epifaunal species that develops from these ratios leads to population densities that stagger the imagination. My associates and I were introduced to this epifaunal complex by a study of a few of the species that crowd upon silstone reefs in the relatively shallow waters of the California shore southeast of Newport Harbor. We have already described the series of zones that reflected the changes in density of the organisms that dwelt from the top to the bottom of the two reefs we studied (Natural History; April, 1961). As pointed out there, the nature and distribution of food cannot be overlooked as a major factor controlling the ecology of these bottom-dwelling marine animals.

If the nature of the substratum is of first importance in controlling the general distribution of benthic organisms, then food availability runs a close second, since food supply and variety will determine more specific regions where various species may exist and also will control, in part, the size of various populations. It is important to note that obtaining food is the task for which animals may exhibit the highest order of structural adaptation. An understanding of these adaptations is needed before we can explain how epifaunal species can exist under such crowded conditions.

If we conceive of the mass of animals existing on submarine reefs as a great machine, it follows that such a machine will function properly only as long as "fuel" in the form of usable food is poured into it. This machine and its physical environment form a biophysical complex, or ecosystem, in which populations of organisms grow and decline, and through which matter and energy flow in a series of transformations and degradations. Where does the energy come from in the first place? Most of us are aware that the prime energy source on land is solar radiation, but many have only a vague conception of the role it plays in the energy cycles of the sea. Let us explore briefly the path between the penetration of sunlight into the water and this radiation's appearance on submarine reefs as food energy. It will be evident then that the epifauna of our reefs cannot exist apart from the inhabitants of the surrounding water (pelagic organisms) and adjacent, level bottom (benthic infauna).

The major categories of food are available in the sea. In probable order of importance to epifaunal animals these are: (1) suspended organic matter (including living plankton and small, non-living organic particles) before it has settled to the bottom; (2) deposits of organic matter (detritus and small, benthic organisms—particularly bacteria—that form a film or scum on the bottom); (3) organic debris meaning those larger pieces of organic matter that derive from destruction of relatively large plants and animals; (4) the larger living animals; and (5) plants of the fixed type (including seaweeds and kelp, and those that form low mats over rocky surfaces).

To take the last category first, surprisingly few marine animals feed directly upon seaweeds and kelp. Among them are the molluscan sea hare, Aplysia and the smooth turban snail, Nucella. However, a larger number of species—many of them...
epifaunal—feed upon smaller algae. Some limpets, periwinkles, and chitons, for example, scrape these algae from rock surfaces with a file-like structure in the mouth. Yet, the relative unimportance of these algae as direct contributors to the sea's food cycles is somewhat unexpected considering the major role that plants play on land in transforming radiant energy into chemical potential energy by uniting carbon dioxide and water into carbohydrates. Here, however, we must emphasize the phrase "as direct contributors." Much of the organic matter of seaweeds is not wasted since, upon death, their substance contributes to the sea's stockpiles of detritus and debris.

Grasses are the great photosynthesizers on land. In fact, man's economy is based everywhere upon the ability of domesticated and wild grasses to provide an abundance of cereals and livestock forage. A host of hoofed animals, and even rodents, are adapted to ingesting wild grasses. True grasses do not exist in the sea, but it is obvious that something analogous to them must take their place. That something is found in the complex assemblage of organisms included in the term plankton, which lies suspended in the upper layers of sea water. The importance of plankton to sea animals is evidenced by the fact that plankton feeds not only myriad small marine animals but also the largest whales and fishes.

Plankton is no taxonomic term, but an ecologic one comprising a complex of hundreds of plant and animal species. Some animals exist solely as plankters; others join the plankton only in the egg and larval stage, eventually transforming into adults. These adults then remain in the free water, as with fish (Natural History, May, 1959), or settle to the bottom, as with such epifaunal or infaunal species as barnacles, starfish, or clams. Although diversity is the hallmark of the plankton, there are a few characteristics plankters share common. All have developed some device that permits them to remain suspended in the water. Most are passive floaters, drifting with the tides, for even the strongest swimmers among them can seldom breast the currents for long. Finally, plankters—at least the important ones for our purposes—are small. But either microscopic or measurable, few tens of millimeters. The two great subgroups of plankton are the phytoplankton (plant component) and the zooplankton (animal component). The phytoplankton designates all plankters that possess chlorophyll and thus photosynthesize. The most important of these are the minute, unicellular algae and dinoflagellates, both of which may be classified as algae. The phytoplankters use the sun's radiant energy to synthesize carbohydrates and other organic compounds. Thus in the minute algae is found the first living
Feeding-pyramid shows possible food movement yearly from plankters, the basic producers, through fixed clam to starfish. Numbers of individuals at each stage and their total weight are given by figures in the pyramid.

The chain of transformations leading from radiant energy to reef animal. The zooplankton, besides the larval stages of benthic animals already mentioned, includes a host of adult species: copepods and euphausiids (crustaceans); arrow worms; and raminifers and radiolarians (protozoans). Some of these animal plankters feed directly upon the phytoplankton; others eat fellow zooplankters. Hence there are food cycles within the plankton itself. In addition, tremendous quantities of both copepods are consumed by epifaunal and infaunal species as currents carry plankton along, while a steady toll is taken by fishes, birds, and baleen whales. Those plankters that escape predation eventually die, settle to the sea bottom, and add to the debris and detritus. And the same again lies in store for all the organisms that feed upon the plankton.

Dead organisms, plant or animal, that remain untouched in the sea, wave zones they are soon broken down into detritus.
into pieces of various sizes. Beyond the waves, carcasses are torn by fishes, scavenging crustaceans, and sea urchins. Thus, although seaweed and kelp are little used as food when alive, they are so used when the alga is destroyed. Large fishes, which in some instances actually feed upon anchored reef animals, will be transformed upon dying into food that can be eaten by their former prey. Carcass fragments that escape consumption as debris accumulate where bacteria, protozoans, minute crustaceans, small worms, and various larvae attack the dead tissue by enzymatically reducing it to compounds that can be used by a wide variety of animals. This decay- ing mass, including minute, attacking organisms, is called detritus. It forms a scum of organic matter over the surface (and even in the interior) of the substratum. Here it will be fed upon by larger animals, or it may be picked up by currents and carried long distances before it settles on reefs or the level bottom. En route, part may be used by suspension-feeders; when it reaches its final destination, it sustains a host of clams, worms, and sea cucumbers that dwell on the bottom and feeds on the accumulated detritus.

It is apparent that here we have outlined still another path taken by radiant energy from its penetration into the water to its appearance on the reef as food energy. The seaweeds intercept part of the sun’s radiant energy and, like the phytoplankton, thereby create organic materials. When the plant dies, part of the tissue becomes debris, to be consumed by scavengers. Dead scavengers—and any remaining plant tissue—will be fed upon by bacteria and other minute creatures, which create detritus while using energy released by the decomposition of the plant and animal tissue. But this process is not self-sustaining. The conversion from alga to bacteria to clam, say, is never more than 20 to 30 per cent efficient at each step. It is evident that this is a downhill series of conversions, maintained only by the constant addition of radiant energy from the sun.

Because most of us are familiar with predator—prey relationships, it is unnecessary to discuss the category of food we call “the larger living animals.” One such relationship is described quite fully, later.

Let us now consider the kinds of animals that are adapted to nourishment from these various food types. Those that use suspended matter are called suspension- or filter-feeders. Deposit-feeders find their sustenance in detritus. A scavenger attacks debris. The carnivores feed upon the larger animals, and the herbivores feed upon the fixed plants.

Since all five classes of food are available to both epifaunal and infaunal animals at some point in their distribution, it follows that the five feeding adaptations will occur in both groups as well. But there are general differences between the two groups regarding frequency of occurrence of suspension- and detritus-feeders. It seems likely that the majority of epifaunal species are filter-feeders, followed in numbers by deposit-feeders. Apparently, except in local situations, the reverse is true among the infauna. It is possible that whether filter-feeders or deposit-feeders predominate in local, infaunal situations is determined by the relative water movement and orientation of currents. Where water movement is slow, fine organic silts collect—usually rich in detritus—supporting relatively dense populations of deposit-feeders. Increased water movement creates coarser bottom deposits that are usually detritus-free. But such turbulence or current action may bring more suspended matter into the area, permitting a predominance of suspension-feeders. Essentially the same relationships occur in the epifaunal domain.

Unfortunately, we do not know enough about the habits of many epifaunal organisms to state positively the relative rank of the three other feeding types. The information we do have points to nearly equal numbers of scavengers and carnivores (the latter slightly in the lead), while herbivores come in a poor fifth. Essentially the same is true of the infauna, although here the gap between carnivore and scavenger may be greater.

An animal’s structure reflects the kind of food it eats. The greatest structural modifications we find among epifauna are those of suspension- and deposit-feeders, and there are close parallels between them. The method of removing suspended particles from water often depends, upon minute, hairlike cilia for creating microcurrents and, second, upon mucus for holding particles which they are carried to the mouth.

Perhaps the most elaborately developed suspension- and deposit-feeders are bivalve mollusks. They have complicated, porous gills, which function less as respiratory organs than as active, food-catching sieves. Although they usually have a pair of large, leaf-like structures near the mouth, callibrachial palps. Both gills and palps are crossed by numerous ciliated trabeculae, and mucous strings, which transport usable food toward the mouth and reject unsuitable particles. The cilia can create noticeable currents; thus bivalves can live in dense aggregations and still pump ample supplies of suspended matter across their gills. Obviously, this method of feeding will permit bivalves to burrow into the substratum, be it rock sand, and still feed upon plankton detritus, provided their siphons be direct or indirect access to the surface. Detritus-feeding bivalves are similar to the suspension-feeders, except usually they have a comparatively large, mobile siphon that supplies up detrital film and carries it in the water stream to the gills, where usual separation takes place. Anemones, or sea-squirts, are suspension-feeders that use essentially the same method as the bivalves. Ectoproct serpulid and sabellid worms, and like, are true suspension-feeders that use ciliated tentacles for capturing and transporting food.

Sea cucumbers present an interesting array of suspension- and deposit-feeders. One suspension-feed type we studied on our California reefs is the small Cucumaria labrum, which lives among thick stacks of fixed clam Chama pellucida. In these stacks it extends branched sticky tentacles into the free water to intercept suspended material. When its tentacles have captured enough food, they are curled back, one into the gut and pulled slowly across the taut lips to sift off the food. The much larger and numerous sea cucumber Parasitostomum parvimensis, on the other hand, is a detritus-feeder. It is found on or horizontal surfaces near the ree's...
Feeder near reef base are typified by starfish, Tang Garibaldi, and sea urchins, all flesh-eaters. Sea urchins are scavengers, starfish may scavenge or feed on live mollusks, fishes eat live animals, and also scavenge.
Sheepheads and Garibaldis, Sefiori and Kelp Bass would often follow the author around underwater, feeding on debris while he collected reef animals.

Smooth tubban snail, Norriusia, feeds on seaweed, much of which has already been eaten. Few of the marine animals feed directly upon seaweeds and kelp.
use, where detritus-rich sediments congregate. It sweeps the detritus, in much sediment, into the mouth by means of fringing tentacles. Finally, a third species of sea cucumber, *Apostynpiella inhaerens*, is found at the base of the reef, where it combs buried detritus by burrowing to rich bottom sediments.

Some crustaceans especially barnacles and certain crabs, are suspension-feeders. Lacking cilia, they have special appendages to create currents and, highly fringed mouth parts trap and pass food particles to the mouth. Sponges, too, are suspension-feeders that lack cilia. Although they may attain relatively large proportions (one species was found to weigh 150 lbs. at the end of its life) they feed essentially like otozoans—taking minute food particles directly into cells for digestion and transport. The unique cells of the sponge that perform this function are called collar cells, because their free ends have a delicate truncate funnel protoplasm that surrounds the base of a whiplike flagellum. These collar cells line the many chambers characteristic of the construction of larger sponges. The continual beating of the flagella propels water through the sponge's porous walls. When food particles borne by these currents touch the collar, they are caught and carried onward to the cell body, where they are gobbled up by a drop of water to form a liquid sphere called a food vacuole, digestion occurs in the vacuole while the food circulates toward the fixed base of the cell. At this point some digested food passes through the cell membrane amoeba-like cells that carry it to lose cells that presumably cannot be digested by themselves.

Coelenterate animals of the reef have diverse feeding methods. Anemones are usually carnivores or scavengers, although there may be suspension-feeders. The same is true of the innocuous-looking little hydroids, some of which have rapacious tentacles and can extend the mouth around bits of animal debris up to ten times their diameter. Gorgonian corals seem to be suspension-feeders, as are many stony corals. Some stony corals of temperate waters, however, are scavengers, as can be demonstrated easily in an aquarium. We have now seen some ways in which the giant machine, as we called the epifaunal complex earlier, with-

draws continuously an impressive amount of fuel—organic matter—from the water and from detrital film. In turn, carnivores of both epifauna and infauna—including the fishes that exist wholly upon food taken from the bottom—find a rich food source among the suspension- and deposit-feeders we have described, and among the scavengers and herbivores as well. The commoner carnivorous invertebrates include such annelid worms as eunicids and glycerids, the nemertean or ribbon worms, many gastropod mollusks, and the starfishes. The most abundant of the latter on our deepest reef (Reef 500) is the opalescent starfish *Pisaster giganteus*. This is a strict carnivore whose food range includes several types of gastropod and pelecypod mollusks. On Reef 500, however, we have found that it feeds almost exclusively upon the fixed clam *Chama pellucida*. Attracted by this close relationship between *Chama* and *Pisaster*, we saw the possibility of obtaining some crude quantitative data on the productivity of this reef.

The concept of productivity and its ecological importance may be explained thus: if we determine the number of *Chama* that exist on a reef and multiply this total by the average weight, we obtain a product that represents the standing crop, or biomass, of this species. This figure, of course, gives us no conception of how much of this organic material is produced in a given time. Such a rate would give us the measure of secondary productivity that the investigator interested in the dynamics of ecology seeks. An accurate figure for *Chama* production rate on our reef could be got only by determining growth rate, life span, percentage of predation, and the like. But in this predator-prey relationship between *Pisaster* and *Chama* we saw an opportunity to take a shortcut to a datum that would give at least the productivity of *Chama* within an order of magnitude.

First, we found—by analyzing many measured samples—that the average number of *Chama* per square meter on the surface of the rock reef was 460. After determining average individual weight (and knowing that there were about 1,290 square meters on the reef), we could calculate that the total *Chama* population of the reef would approximate 552,900, and that this total would weigh about 15 tons, of which 11 tons would be shell, and 4 tons wet weight of flesh. It was obvious that this mass represented an accumulation of several years. Exactly how many years this process required, however, is anyone's guess.

Next, we determined the number of *Pisaster* on the reef by a series of direct counts, and found it to be stable at 500, or about one starfish for each 1,100 *Chama* of all sizes. We then collected representative starfish and clams and placed them in laboratory aquariums. Over several periods, each two weeks long, the starfish were allowed to feed freely upon weighed clams. It was found that the average *Pisaster* ate 0.6 *Chama* of various sizes per day, or about 220 per year. This meant that the reef's 500 starfish would consume a calculated 110,000 clams a year, or about 20 per cent of the estimated total *Chama* population.

Having computed that there are 4 tons of *Chama* flesh on this reef, and considering the population stable, it follows that the clams must produce each year at least the amount of flesh eaten by starfish. Thus, productivity of *Chama* on the reef has a minimal estimated value of 20 per cent of 4 tons—or 1,600 pounds yearly.

This figure allowed us to estimate the amount of organic matter (largely plankton) that the *Chama* population eats in a year in order to maintain itself against the depredations of this one species of starfish. Assuming that *Chama* is as much as 25 per cent efficient in converting food to flesh, the species must consume more than 3 tons of plankton yearly on this small reef (figure, p. 49).

*Quite* likely the *Chama* could get along without the starfish that preys on it and without the other species that inhabit its stratifications, but the reverse is surely not true. It is thus of interest to speculate upon why *Chama* reaches its maximal densities upon the upper part of Reef 500. Aside from the nature of the substratum, the two physical factors that seem to exert the greatest control on these growth characteristics of *Chama* are water movement (as wave surge) and water temperature. The force of wave turbulence varies markedly on Reef 500: it is greatest near the top, moderates sharply as one descends along the side, and is virtually non-existent in the zone of quiet water a meter or two above the
Sea urchins form circle around dead guitarfish as they approach to feed.

sea bottom. At several points high on the silstone reef, we have observed *Chama* stratifications of more than 4,000 individuals per square meter; near the bottom, the *Chama* density may drop to zero. Evidently, such dense stratifications can persist only where turbulence is sufficient to flush water, carrying food and oxygen, through the stacks’ interstices. But, as noted earlier, this water movement must not be too severe, for in such places *Chama* is either absent or present only in reduced numbers.

Temperature may have both direct and indirect effects in controlling the major distribution of *Chama* and development of stratifications. The direct effect would control the growth rate needed to develop and maintain these dense populations. The indirect effect is found in the role temperature plays in determining the relative amounts of plankton to which *Chama* will be exposed in the course of a year. Both direct and indirect effects are related to the thermocline—a zone of rapid temperature change related to a change in depth. To qualify as a thermocline, the temperature gradient must change at least one degree centigrade for each meter change in depth. In the area of Reef 500, the seasonal thermocline prevails during the five or six warmer months, when it hovers between depths of eleven and fourteen meters, with significantly warmer water between the surface and the thermocline than below. Plankton populations often reach peak densities when the thermocline prevails. Since there is little mixing of water across the thermocline, for many days we may observe murky, plankton-filled water above the thermocline and fairly clear, plankton-free water below. It is probably more than coincidence that *Chama* on Reef 500 reaches peak densities above the zone of the thermocline.

On balance, we tend to conclude that water movement—specifically, the degree of turbulence—is the prime cause of the marked changes in frequency distribution observed for many organisms on our reefs. This could explain, for example, why we find the best development of zonation on large reefs oriented at right angles to submarine wave movements. This offers the most resistance to wave forces and provides the most turbulent waters at the top. It would also account for our observation that small reefs and those with axes parallel to wave movement tend to have a very wide life zone of the sort that appears as a response to more uniform turbulence from the reef’s top to bottom. This view leads us to anticipate that deep reefs—where turbulence is minimal, regardless of orientation—may show less zonal differentiation.

Both the turbulence and temperature can account also for the fact that we see a general reduction gradient in numbers of species and individuals as we descend. Moreover, it is a reason to expect the number of filter-feeders to drop as we descend along the side of the reef, while the proportion of detritus-feeders and scavengers will rise. The common scavengers of these reefs are sea urchins, large serpent starfish, and certain hermit crabs, all confined to the two deepest zones. There they find a rich supply of debris that falls from upper parts of the reef under the influence of turbulence.

Looking to the future, our observations seem to lead to the conclusion that the great limiting factor in the future development of epifaunal populations is the relatively small amount of substratum available. Haps this can be dismissed as an endemic consideration, for the immediate problem is simply one of survival in the face of man’s activity. We are now aware of the delicate interdependencies that exist between and among components of pelagic matrix and the benthic, limited area. It is reasonable to suppose that such concepts can be expanded to encompass the world sea into a giantic ecosystem. If we can act on this, then no one part is completely isolated from any other part. A concept should caution man to be careful thought to his treatment of the sea, once thought inviolate, particularly with regard to waste. At some unpredictable concentration level, these accumulated wastes might trigger a chain of ecological effects that would produce very widespread biological and geographical effects.

Sculpin, normally found near reef or on bottom, is venomous relative of the rockfishes. Spines contain poison the movement of energy from the benthic matrix to the plankton, producing a more than ample food supply for suspension-feeders of the epifauna. Then again, as we have seen, not all food chains are simply unidirectional. There are, in electronic terms, feedbacks in the chains, such as observed in the formation of detritus in the benthic matrix, in which food materials are used and reused until most of the matter and energy of biological value is exhausted. The depo-
On spring migration, barren-ground caribou, above, file over frozen lake.

Arrows on map indicate chief spring migration routes. Winter-grazing occurs in shaded areas.
Migrating Caribou

Barren-ground herds face a serious threat to survival

By A. W. F. Banfield

The reindeer was a characteristic mammal of the cooler phases of the Pleistocene, associated with a tundra and taiga vegetation on the edges of advancing or receding glaciers.

In a similar way, the caribou adapted to Arctic and subarctic America. Here it served as the cornerstone of the comparatively Stone Age cultures of two distinct nations—the Eskimos and Chipewyan Indians. The latter group were known as the caribou eaters, and were almost totally dependent upon the animals for such basic necessities as food, hide clothing, tool handles, sinews for sewing, and oil for lamps. The Eskimos were generally less dependent upon the animal, basing their economy more upon the marine mammals—seals, walrus, and lesser whales—although they turned to the caribou for such important items as winter clothing.

The North American Eskimos and Indians relied upon a primitive hunting culture. They speared the migrating caribou herds from canoes and kayaks. They captured them at water crossings or in pounds made of spruce tree fences (or columns of stones on the tundra). They sometimes stalked with bow and arrow, the hunters often disguised in caribou hides and antlers. Such methods were
Dr. Banfield, now Chief Zoologist of the National Museum of Canada, took part in the Canadian Wildlife Service's study designed to survey and conserve barren-ground caribou.

probably not unlike those of our Stone Age ancestors, and could still be observed in certain parts of northern Canada until about 1950.

These, then, were the sights that greeted the first European explorers to the northland: great herds of caribou roamed the Arctic tundra in countless numbers, comparable to the buffalo herds of the prairies, followed by nomadic bands of Indians and Eskimos. However, the advent of Europeans upset the centuries-old balance between caribou herds and their human predators. The fur trade led to long winter trips to trap the fur bearers that had been taken only incidentally before. Larger dog teams were needed, as were large caches of caribou meat to feed the trappers and their dogs on the trail. With these changes were introduced the tools necessary to facilitate the killing of caribou—the white man's firearms.

The remoteness of the caribou's range, together with the sparse and primitive human population, hindered a really accurate appraisal of the animal population. Exaggerated estimates ran as high as 100 million. The famed naturalist Ernest Thompson Seton estimated the caribou herd at 30 million in 1907. As late as 1938, the caribou population was estimated to be as high as 21/2 million animals.

With the increased postwar tempo of development in Canada's Arctic and subarctic regions, fears for the fate of this important natural resource were expressed. Federal and provincial authorities recognized the urgent need for an intensive investigation and undertook a co-operative preliminary survey in 1948 and 1949. Previous attempts at estimating the caribou population had been handicapped because of the slowness of the traditional northern transportation methods of dog team and canoe. However, pioneer aerial searches for lost bush pilots in the Canadian Arctic during 1937 and 1938 led to the des-
Uncontrolled hunting by Indians, who spear caribou from canoes, results in carnage, above. Each year, thousands of carcasses are thus abandoned and rot.

devlopment of the aerial caribou survey technique. During spring migration the herds travel in closely packed columns. They tend to follow frozen lakes and rivers. On sunny afternoons they bed down on the snow-covered lakes and are easily photographed and counted from the air.

The preliminary aerial survey in 1948 and 1949 indicated an estimated population of about 670,000 animals between Hudson Bay and the Mackenzie River. The annual crop of calves was estimated as 145,000. The number killed every year by hunters, based upon hunting returns, was about 100,000. Wolf predation, diseases, accidents, and severe weather caused losses that appeared to exceed the annual increase and to result in a declining population. Many other factors—loss of winter range from forest fires, blizzards at calving time, crusted snow—were thought to cause catastrophic losses at certain times and places.

A resurvey was undertaken during the winter of 1955-56 with alarming results. On the basis of the same aerial survey technique, the population was estimated to have dwindled to about 275,000 animals. Although some drop in the population had been anticipated, as a result of the preliminary survey, the actual decline exceeded the expected by about 50 per cent.

Steps were taken in 1957 and 1958 to rectify the situation. Teams of specialists from the Federal Department of Northern Affairs and Indian Resources, the Federal Indian Affairs Branch, and the Provincial Game Branches of Alberta, Saskatchewan, and Manitoba co-operated in an intensive investigation into the basic causes of the caribou decline. The prevailing needless hunting waste of caribou by Eskimos and Indians was recognized, and vigorous educational steps were taken along sound conservation lines by means of cartooned pamphlets, film strips, posters, and courses in the schools. The hunting laws were tightened, bag limits for natives and resident Europeans were reduced, non-resident sport hunting was eliminated, and cows and calves were protected in spring. Ultimately, district quotas may be set. Auxiliary food supplies of whale, walrus, and bison meat were utilized to replace caribou, and storage facilities were established in some settlements.

Finally, a vigorous wolf control program by paid government hunters was undertaken for the first time over a huge area of subarctic Canada, resulting in a significant drop in the number of wolves. During control operations over a five-year period, about 4,000 wolves were taken—about half the estimated population.

Although all scientific reports have not yet appeared from the most re-
Migrating caribou average 19 miles a day, and some travel over 800 miles.

On northward trek, this herd, below, is sent scurrying by approach of man.

Pemmals, the caribou feed principally forichens and some small tree growth.
cent co-operative research project, it is known that significant advances have been made in our knowledge of the role of snow in the caribou's food habits and the effect of "windchill" on newborns. In addition, new information on caribou migration was obtained by biologists in light aircraft "leapfrogging" after the migrants from the winter range to the summer range 800 miles away.

PRESSURE has been taken off the caribou in still another way as new economic possibilities have been opened to the Eskimos. Work in mining and military establishments, in social services, and in aerial transportation has reduced the need for caribou as the main source of sustenance. This change came at a fortuitous moment, for the disappearance of the herds resulted in starvation in some very remote Eskimo camps in Kee-watin District, and caused grave hardships over a much larger area in northern Canada.

There are some who say that northern development has doomed the caribou in any case, and that we should not concern ourselves with its fate. But the stunted subarctic forests and tundra pastures underlaid with permanent ice are of little use for modern forestry or for agriculture. The caribou is the animal best adapted by nature to utilize these habitats. It is suitable for an extensive type of herd husbandry, and if properly managed could continue to provide bounty "on the hoof" to northern residents remote from supplies of domestic beef.

On trail of caribou, a wolf streaks across snow, right. But a worse threat to caribou's survival is human hunter.
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NATURE and the MICROSCOPE

Varieties of Instruments

By JULIAN D. CORRINGTON

Thus far in our explanations we have achieved simple definitions of magnification and microscope: any view of an object closer than the ten-inch near point is a magnified one, and any appliance that can provide such a view is thereby technically a microscope. A drop of water hanging in a wire loop, spectacle lenses, and the pinhole card were cited as examples of devices that fit this definition but are not ordinarily called microscopes—by common usage we restrict this term to an instrument consisting of one or more lenses, held in frames or tubes for manipulation.

When microscopes were first invented, the interest in them centered around the fact that one could see finer details in an object, or see things never before known. Pioneer workers looked at anything and everything, initiating a great curiosity in the construction of all material objects. But it soon became evident that early microscopes had their limitations, a recognition that led to improvements in existing equipment and to the invention of various specialized instruments for particular purposes. Today, this specialization has gone so far that the number of diversified types of optical instruments is almost legion: whenever a new need arises, the manufacturers have responded by developing a suitable magnifier, and this month we will describe and classify the principal kinds.

Thus earliest magnifying instruments were all simple microscopes, after the fashion of the hand magnifier in use today. Commonly, a single biconvex lens is mounted in a tube or frame with a handle, and is held close to the object on one side and to the eye on the other. An enlarged image is provided, but, as shall be explained later in this series, such images are subject to a number of defects, overcome for the most part by combining two or three lenses to work together. When two lenses of different composition and shape are cemented together, the magnifier is termed a doublet; when three, it is a triplet or triple achromatic—the finest and also the most expensive of hand lenses. The entomologist and the botanist use this kind of aid. Magnifications most frequently seen are 5X, 10X, 15X, and 20X, with the most desirable strength for an amplifier.

Even with instruments of this class there are specialized designs. The reader has a large diameter, 2X or 4X, and a long handle, and is made to assist the elderly or persons with weak vision who wish to readinary type; the collector who scans age stamps, coins, small insects, and like; the etcher or engraver; or the who inspect the fine art of photography. The fingerprint reader equipped with engraved scales orings, which mark off measured areas. The geologist uses a reader with sorts of scales to count soil particle

The linen tester folds flat in a pocket. When opened it provides a fixed focus covering exactly one square inch of field. Its original purpose was to help the textile buyer count the number of threads per inch in woven goods, but it has many other uses. The loupe is in hand by the eye socket bones, leaving the hands free: it is employed by the wheller who inspects the works of a watch or gemstone settings in rings.

When mounted in a frame an equipped with a focusing gear, it is a magnifying glass, augmented with a substage and spiral spring clamps and base, the magnifier becomes a dissecting microscope. Its hands can then work with the specimen.

The compound microscope has sets of lenses. One is close to the objective: the other, some distance above the first and close to the eye, the observer, is called the ocular.

Such an instrument provides magnifications to a maximum of 200X.

Strangely enough, there has never been a universally adopted name for ordinary compound microscope. It is termed the laboratory microscope although this is obviously a poor designation, since almost all microscopes are intended for use in laboratories of one kind or another. It has also been called the biological microscope, but a large proportion of them are employed in non-biological work. So far we have not settled for the ambiguous name of...
radical innovation was the binocular microscope, which did away with the usual unnatural use of one eye, as from the single objective, it is then redirected by systems so that the observer sees it in two pieces in which the tubes are either parallel or convergent. All research and other types of microscopes may be purchased with either monococular or binocular stands, and many makes have interchangeable bodies—the binocular for visual observation, the monocular for photomicrography.

The 3-D microscope is a partner rather than a competitor of the ordinary compound instrument, as the two kinds are usually employed with different classes of objects. The 3-D is preferred for whole objects, such as a small animal (planarian), embryos, parasites, insects, small fruits, seeds, small skulls, and for examining sections of a whole organ (a kidney, for example).

In regulation procedures the illuminated circle that is visible—the field of the microscope—is always brighter than any object. Therefore, this method of observation is termed bright-field microscopy, a designation made necessary by the discovery of an alternate and opposite effect, dark-field microscopy. In dark-field work, an annulus, or circular stop, is placed below the condenser. This has a black metal center that cuts off all direct light from the mirror. Rays that pass through the outer annulus, or open circle beyond this central stop, are so oblique that, having traversed the object on the slide, they proceed onward at such an angle that they do not enter the objective lens at all. Therefore, when the observer looks down the eyepiece, he does not see these rays and the field appears perfectly black. Meanwhile, particles in the object have intercepted some light rays and refracted these through the tube so that they become visible to the eye. Each such intercepting particle becomes a new source of light, a phenomenon named Huygen's Principle, after its discoverer, a seventeenth-century Dutch physicist. The particles seem to glow as if self-luminous. A paramecium will scintillate,
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as if inwardly illuminated as it swims about in an inky-black field. This method reveals a great deal of information as to the surface markings, and has proved a valuable supplement to bright-field microscopy. Any microscope equipped with a condenser may be used for dark-field study even by adding a dark-field stop or by substituting a special form of condenser.

I s geology and chemistry another principle concerned with visible light has long been in use. Colorless light, such as that from the sun, vibrates in all directions around its axis of forward propagation, but certain substances—such as a calcite crystal or the synthetic material Polaroid—can split the light into two rays. One, the extraordinary ray, is refracted out of the picture; the other, the ordinary ray, is polarized, the vibrations being restricted to a single plane. If we place a circle of Polaroid film below the condenser, the only light that gets through is polarized; hence, this film is called the polarizer. This light still looks as usual to the observer—he cannot see that any change has been effected. If another such film (called the analyzer) is now placed upon the eye-piece, a number of consequences are possible. If the planes of polarization of both films coincide, the light coming through seems like ordinary light, and no visible difference is observable in the microscopic image. The optical slots of the two Polaroid films are parallel. As the analyzer is rotated, however, its optical slots finally are at right angles to those of the polarizer. Light is then extinguished, and the field is black.

When an object is illuminated by polarized light rays from below, one of two things happens. If the object belongs to a class of substances termed optically active, it will repolarize the light and transmit such altered rays to the eye-piece. The amount of repolarization depends on the nature of the material. If the object is optically inactive, it will not repolarize the light, and, as a result, will show no effects.

When working with an optically active substance, there comes a point, as the analyzer is rotated, at which the optical slots are crossed at right angles and the field appears black. This place may be recorded on a scale of angular measurement, and thus the angle of extinction determined. Inasmuch as this angle differs for each different crystal system, an identification of the type of system being observed may readily be made. This is a great aid in solving unknowns of optical mineralogy and chemistry. Between white light and extinction, gorgeous color effects are observed, and these have been preserved in the form of spectacular colored movies of crystallization, especially in the case of organic acids. In biology, too, certain substances—notably keratin (horn) are optically active and the polarizing microscope is an aid for identification, these materials however they occur.

UNTIL quite recently, all microscopes used light to produce an image; no prefix to the word microscope was required. But the twentieth century has the discovery of other sorts of energy that could be used to form images. For example, the electron microscope. The phrase light microscopes came being for regulation instruments. Why, then, are not light microscopes?

Physicists know that visible light is only one small portion of an enormous band of radiant energy. When a source of energy—such as the sun, a candle, hot stove, a radio-transmitter or X-ray tube—is emitting energy, the particular type of emission depends on frequency of vibration and the resultant wave length. Long waves, like those emitted by shaking a rope up and down, have a low frequency (number of vibrations per second), and the wave length is measured in meters. When the w
of vibrations per second is stepped up, the wave lengths become shorter: all more vibrations, and we get into the realm of blue and infrared light, invisible to the human eye but capable of reception by other means.

In the first half of this century it was discovered that objects are located in the heads of the pit vipers (including American species of moccasins and rattles) which are sensitive to emanations of energy at the infrared level. This is a remarkable adaptation that enables these snakes to strike at warmed prey at night. Man has no organ he can register rays of this frequency. His cameras can, and X-ray pictures of cities may be made even at night or through layers of clouds. Visible light comes next, occupying a single octave of the whole electro-magnetic spectrum. Above this comes ultraviolet, not detectable by man vision, but capable of being seen certain other animals. Cameras dipped with the proper optics and film by reproduce subjects illuminated by ultraviolet, so pictures taken through a microscope furnished with ultraviolet micro-quartz lenses—may register details that are too fine for recognition by the naked eye. Successively higher in the spectrum are soft and hard rays, electron beams, and, finally, cosmic rays, which come to us from outer space at an enormous frequency and extremely short wave lengths.

Today, we have ultraviolet microscopes. X-ray microscopes, and electron microscopes, used by specialists in biological research, medicine, and industry. A vivid analogy draws a comparison of performance of the various instruments with various sizes of mesh in nets. In using a light microscope, wave lengths can be compared to a coarse net, adapted to catch only large creatures—sharks: all smaller fishes get through and are not light. In succession, the other forms of energy compare to meshes continuously finer, the electron waves, finally, being mesh that entangles minnows. Accordingly, detail so fine that it escapes observation in the light microscope will be apparent and revealed by the electron apparatus. This depends on the resolution or resolving power of a magnifying instrument—its ability to render detail. The shorter the wave length of energy used, the finer the detail that is seen. Resolution and magnification are the most essential of microscope abilities: the two, resolution is considered the more important.

Meanwhile, the light microscope has recently been the source of a thrilling discovery—the phase-contrast principle. To understand this newest and most important development in light microscopy of the past hundred years, we must digress to explain the differences between transparency and contrast in the specimen.

In the routine procedure of micro-technique—the preparation of materials for examination under the microscope—the subject must, at some stage, be rendered as transparent as possible in order to transmit the light coming from the mirror below the stage. Thick or darkly pigmented objects will not pass enough light through to make them visible; they are more or less opaque and hence useless for observation save by incident illumination. Hence, thin sections of tissues and organs are cut on a microtome—a refined, laboratory example of the butcher's meat slicer—and mounted on slides. Along with other steps, they are treated with xylene to confer transparency, but the xylene defeat the very purposes of the technique. The specimen can be made so transparent that no detail at all can be seen.

Try this simple experiment. Place some colorless glass beads (or broken bits of glass) in a test tube or small glass container of benzene. Then, try to find the beads. You will not be able to do so, because the fluid and the glass have the same refractive index; that is, they bend the entering light rays to the same degree, and the emergent rays all appear the same, with no distinction between what is benzene and what is glass. But now place some colored glass beads in the same reagent; they may be discerned perfectly. If the beads are red, for example, the red dye in the glass absorbs light rays of the green-blue-violet end of the visible spectrum, refracts those of the red end to our eye, and thus appears red. The benzene does not do this, and so the factor of contrast is provided. The heads are still transparent, but are rendered distinct through contrast with the surrounding. The same applies to tissues: we stain them with biological dyes for contrast and then put them through xylene, in the process called clearing, to yield transparency.

In phase-contrast microscopy only unstained material is used, but the entering light is altered so that the background illumination is seen by wave lengths of ordinary light that are other than those passing through the specimen. An annulus is placed below the condenser and another, one called the phase plate, is situated in or above the objective lenses. Either or both of these rings may be so treated as to retard or advance the phase of the wave lengths of transmitted light. This provides contrast between the object and background without interfering with the transparency of either.

Waves are undulating, with crests and troughs. If the background light waves...
arrive at the focal plane of the instrument at their crests, and the waves refracted or diffracted by the specimen also arrive at their crests, there is reinforcement, and light seen by the observer is bright. If one set of waves arrives in crest and the other in trough, there is extinction, one set canceling the other. But if, by means of the phase-shifting annuli, one set arrives out of phase by one-quarter of a wave length, object and background exhibit contrast, but without loss of transparency.

The effect is similar to that of staining, but no dyes are used. Indeed, the process has been referred to as “optical staining.” Living cells, such as amoeba or paramecium, are viewed in their natural movements, and are seen with great clarity of detail, impossible by any other method. For instance, in the biological laboratory it has been customary to have the student first observe living para- mecia for behavior. He is then given fixed and stained slides of the dead animals to study—for such structural detail as nuclei. When the microscope has phase-contrast attachments on it, the nuclei show in the living protozoans as well as if they were stained, yet the animal, all unaware of this concentrated human interest in its affairs, goes about its daily business of living.

A completely different set of applications is introduced by the comparison microscope. Here there are two objectives, several inches apart, scanning two different fields of view, but with a single eyepiece. The two tubes are capped by prisms that direct the two separate images into a single field of view, divided by a hairline in the center. The observer sees the image from the left-hand objective displayed in the left half of the eyepiece field while, across the hairline, the image from the right-hand objective is seen. The effect is especially helpful in chemistry, industry, and especially in scientific crime detection are made possible with this microscope. In one form, the colorimeter, a dye or paint of known saturation is held by a tube below the right-hand objective; an unknown—be it tested, compared, or matched—is in the left-hand tube. By focusing, the two colors may be seen side by side in a single field. A measured amount of pigment may be added to the unknown until the two colors agree precisely. The hemoglobinometer is used to match samples of blood. The unknown is adjusted until it matches the known and a direct reading is then made on a scale.

Fingerprints may be matched, or proved unlike, so exactly by means of this instrument that enlarged photomicrographs, for projection in the courtroom, are now admissible evidence in all legal proceedings for personal identification. The left half of a fingerprint is

seen in the left half of the field, right half of a supposedly identical gerprint in the right field. If the prints are, in fact, from the same digit, all the friction ridges will match perfectly across the central hairline. If the two prints do not match, it is clearly not made by the same finger.

MANY variants of all of these instruments are possible. The shop microscope may be held in the hand, permitting an inspector to examine castings, screw threads, and other chined work for imperfections; the tallograph makes photomicrographic metal alloys to analyze the blend of, and carbon or nickel in steel metal; for example; the optical pyrometer allows an inspector to look into the tip of a heat of a blast furnace from a distance and read the temperature on a scale. The refractometer gives the refractive index of translucent substances at a glance, the ophthalmoscope is used by physicians in scanning the blood vessels of the retina of your eyes; the otoscope is designed to look into the ear. Large or miniature microscopes are less expensive and there are smaller models for the youngster or beginner. Some of these are very good, but worthless examples are often offered for sale. There are special microscopes or accessories for taking either still or motion pictures through the instrument, for making drawings or measurements, or for projecting an enlarged image on a screen.

While this by no means exhausts the list, it will serve to give a picture of the great multiplicity of magnifying instruments available today. The reader may well ask, “This being the case, what microscope is the one for me?” All depends on what you want out of a microscope. It is best to buy an ordinary compound type first. If and when a specialty has been decided upon, you may know what additional optical aid is required. I shall be glad to answer readers of this department who wish to pursue the question further. Add inquiries to me, at NATURAL HISTORY.

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COVER: For years, both Biblical scholars and botanists have attempted to identify the many plants mentioned in the Scriptures in a search for clues to the daily life of the period. The flowers in the cover’s “bouquet” grew in fields of the Holy Land in Old Testament times. Clockwise from the top: iris, narcissus, dandelion, saffron crocus, tulip, hyacinth, and stardust. Surrounding anemones in the center. On page 30 begins a discussion of uses to which plants were put in the ancient Mediterranean area, illustrated with Anne Ophelia Todd’s magnificent paintings in black and white and in color.

The American Museum is open to the public without charge every day during the year. Your support, through membership and contributions, helps make this possible. The Museum is equally in need of such support for its work in the fields of research, education, and exhibition.
MUSEUM MEMO

BY JOHN O'REILLY

The American Museum of Natural History has long portrayed various aspects of man. Primitive cultures have been shown through habitat groups and displays of man's tools, utensils, and art. In more recent years, there has been a tendency to delineate man's place in nature, displaying his destructive and constructive activities on the earth he inhabits. Now, for the first time, the Museum has taken an apart, enlarged the delicate mechanisms that make man run and examined him as a biological phenomenon.

In the new Hall of the Biology of Man, Museum technicians have created a series of displays that are instructive and beautiful. The concept of this hall of human biology—is the first of a series of halls—was developed fifteen years ago by Dr. Harry Shapiro, Chairman of the Museum's Department of Anthropology. Recently we toured the exhibits with Dr. Shapiro. He was fagged from handling the problems that always arise in the weeks before the opening of a hall, but his enthusiasm for his pet project was strong as ever despite last minute crises.

I'd like to emphasize this," he said. "In planning this hall, we realized that people will come here who don't have any background in this subject. There will also be added students. We have had to plan the exhibits so they are meaningful to both groups. If you want to take the time, you can learn a great deal here. It is plain, scientific, dramatic, and it's got a lot of solid stuff in it."

Dr. Shapiro then moved about the hall, discussing each of the displays. He began with a huge life-size mural on which a great spiral depicts the span of creation through two billion years. From the first one-celled creatures' appearance up to the little sliver of time that represents the age of man. Across from this, against a mural representing the many kinds of primates, are seen the sculptured heads of fourteen types of fossil man.

The second section of the hall begins with a greatly enlarged human cell, fashioned of plastic arranged in layers that show the details of its structure. Models of different types of cells show how they are specialized to form skin, nerve, muscle, and other parts of the body. The reproductive process is explained and traced by models of the male and female reproductive systems, the formation of eggs and sperm, fertilization, embryology, and birth.

In addition to models in plastic, there are nine actual fetal specimens, tracing the embryo's growth from nine weeks to seven months. Here and there in the hall are other such specimens, including an entire digestive system and a human heart, preserved by impregnation with plastic. We were much impressed at seeing an actual human heart.

But even more impressive was a plastic model of a heart in which the valves open and shut as "blood" is pumped. This and a number of other models create amazing effects through the use of plastic that transmits light from edge to edge while its surface remains unlit. If the surface is carved or etched, light appears there. By superimposing a number of etched layers, colored light produces an illusion of depth and movement. This technique is used to reproduce the circulatory and pulmonary systems, as well as for an exhibit in which an ovum leaves the ovary and travels to the uterus.

The other inner workings of man, from his digestive system to his emotions, are all treated in this magnificent hall. As a focal point, the "transparent woman," a life-size figure in clear plastic, stands before a panel of black mirrors. The mannequin turns slowly on her base, as a recorded voice describes internal structure and the plastic organs light up one after another.

As we were about to depart, another aspect of the hall became evident. The walls and columns are done in plain gray and white and the cases are aluminum: the exhibits, themselves, provide the hall's accents of color. The over-all effect is striking, and quite different from any other of the Museum's many halls. We stood there for a while, taking in the full sweep of this $150,000 masterpiece. "To me," Dr. Shapiro said at last, "it is the culmination of a dream."
Today, many sciences are made more readily comprehensible to the layman through popular paperback accounts written by scientists themselves. But the discipline rejoining in the un¬
gainly name of “ethnomusicology” has not been so popularized. This is a pity, because this field of study touches every one of us, and puts a wealth of valuable and important material at our disposal.

To benefit from a knowledge of this young science, the layman does not have to be a skilled musician, for ethnomusicology is primarily a study of music in its social context. The student is not, or should not be, interested merely in the technical differences between the music of different peoples, but rather in why different peoples make different music, and what significance can be attributed to such differences. So the layman, if he were to learn something of this science, would not add to his total sum of knowledge alone; he might also find a new world of delight and interest. Above all, he would learn a great deal about other peoples—as well, perhaps, as his own—that might surprise him.

Even in the absence of some book called Popular Ethnomusicology, a start is possible, thanks to some excellent recordings that are available on the commercial market (most are accompanied by detailed explanatory texts). I shall mention here only certain records put out by three of the major American companies in the field. Necessarily, then, there will be omissions both of deserving records and of deserving companies. The former is inevitable: the latter, however, is deliberate. The companies mentioned have, to varying degrees and in varying ways, consciously dealt with the problem of issuing records that, however good and worth while, are not likely to return any appreciable sales profit. These companies do so because they realize that folk and primitive music are an essential part of man’s musical heritage.

I have also enlarged the field, for the purposes of this review, to include religious music, because this is a fundamental aspect of music, as much in an African chant as in Mozart’s Requiem or today, perhaps, in rock-and-roll. The border line between folk, primitive, and religious music is a tenuous one, and the division I give here is quite arbitrary. Perhaps this point is best seen in historical perspective.

Archaeology tells us something of the early beginnings of music. A comparative study of still-existing “primitive” (in the non-derogatory sense of “less complex”) societies, in turn, can tell us even more, for here music is often used much as it must have been from the first dawn of humanity. We have in our possession drums, whistles, and harps dating back thousands of years; from all the evidence available, we come to the conclusion that music was first and foremost a means of communication. In this context, communication involves more than jungle drums and the “bush telegraph.” Certainly drums, hollowed logs of wood, trumpets, and other instruments were and still are used to communicate between one village and another over considerable distances. But music was also thought of as having the power of communion—with divine spirits or with departed ancestors.

When the Western world inherited the Greek musical tradition, it inherited two things. One was a well-established body of musical theory, based on a strong Oriental influence. This involved the belief that music was inextricably bound up with religion, which demanded the exact performance of special modes for each festival or ritual. Without the music, the ceremonies were considered ineffective. But we also inherited the seed of intellectualism planted by Plato and Aristotle, who believed that music was more than form: that it was essential to the general process of education, shaping the mind and the soul.

The philosophers included music among the mathematical sciences, by which man might understand the harmony of the universe. This germ of reason was eventually to split the course of musical development into two distinct directions. One was the development of what we call “art music.” The clergy took over the intellectual development of music, as they did the practical development of its function in Christian ritual. From this body of scholars emerged a totally new, highly formalized theory of music, and the acceptance of the tempered scale with all its harmonic ramifications (this had been tried, ages before, by the Chinese, and rejected as not in consonance with the music of spheres). Along with this development emerged new phenomena: the professional composer, the professional performer, and a purely spectator audience.

At the same time, the old minstrel continued, although now divorced from its original religious association. This was what we call folk music. It was still made by the people, with professionals earning only in the form of wandering minstrels. And its function was still the same: the basic function of communication. Minstrel was the one great means of spreading local or national news in days, not so long ago, when the bulk of the population was not yet literate. Folk music was also the means of consolidating and preserving traditions, of passing on from generation to generation a great body of knowledge that we sometimes condescendingly call “folklore.” Much of this folklore has been lost and, at first, was frequently disguised (sometimes liberately) in the form of allegory, with a remainder often difficult to interpret accurately. But a great body of traditional music—dating back to our prehistoric past and linking us in formal and informal function with even earlier beginnings—still waits to tell us something.

Let us look at some of the records that are readily available. Folkways records head the list, as the only commercial company dealing exclusively in the field. They list some hundred recordings, every one of which is maintained permanently on issue. In addition to their ethnic series, they have a religious series, one on science, one on musical and educational Americana, and one on literature, and others specially designed for children. They also have a vast backlog, which doubtless would be issued if their budget were a little higher above the marginal level.

With a public that does not respond kindly to anything that is not in style or at least in ultra hi-fi, Folkways, no very easy means of doing the job, is set out to do—to preserve and present authentic documentation of different types of music and sound. With so much charlatan, gimmick must be eschewed where the dangers are very real. It is
Fortunately, not unknown for recording engineers to boost certain parts of a musical performance, to alter the balance deliberately to single out one instrument, and then to put the whole bag of tricks (and that is precisely what it is) through an echo chamber.

The result is fascinating to listen to, yet it does not answer the question that folkways try to maintain: that the listener should hear just about what he could at an actual performance, given in a natural surroundings rather than in studio. This is no academic quibble. Of major importance for, once the balance has been distorted, there is no way of determining the original balance, and even more dangerous, recordings in be made this way to suit individual ecies, if not simply to better sales.

Columbia Records, which began a World Library of Folk and Primitive Music some years ago, has not added to its collection lately, presumably from lack of adequate response. It is true that schools ke an active interest in the excellent recording, but the problem is one of the new supermarket approach to record distribution, where a fast turnover is more important than a good selection. None- theless, Columbia has an excellent section of subjects in its “World Library,” and good or even better records its general catalogue.

Westminster, similarly, has an excellent series of records, although specializing folk rather than in primitive music. This house has chosen to deal with rickly-dlingge and success—with aim. With other areas it deals equally ill, but in less detail.

Using these three sources intelligently, even the neophyte can trace the whole development of music and its use in human society from the earliest time. We might just as well start with the most difficult-to-listen-to rec- ods. And it is no help when the quality of the recording is as abominable as in a Music of Peru (Folkways). I have seen some very poor recordings my- self, and know the difficulties involved, there seems to be no reason for the ground noises, grounding hum, and verbal low quality found on this record. There must be better musical material available from Peru; academic accuracy excuse for poor quality. But, gen- erally, Folkways quality is excellent, there are always explanatory texts, with biographies, to let the listener a clear awareness of what he is hearing, spoke earlier of music as a form of communication. This, perhaps, is really “music,” but it is highly signifi- cant, and fascinating to listen to. Drums of Yoruba of Nigeria (Folkways) in- cludes recordings of the “talking drum” actually imitates the tonal pattern the spoken language, and the other examples will give the new listener a good notion of the high degree of rhythmic complexity he will meet even in the most primitive areas. Other African rec- orders by the same company give further examples of the use of music for communica- tion, from Tanganyika, and for magic. Almost every African album has examples of all these elements—and among the best are Tuareg Music of the Southern Sahara, The Topope People of the Congo—an excellent album from every point of view—and Wolof Music of Senegal and the Gambia.

The Tuareg album will give a good idea of some of the peculiar vocal tricks one is apt to find beyond Western shores (particularly in the final dance). The Wolof album is important in effectively demonstrating the tremendous influence of Islam in West Africa; band five of the first side is doubly interesting, not only because it is connected with the Islamic concept of the Holy War that was of such major political importance in this area, but also because of the fine recording of two small halam lutes.

Columbia has two albums of African music—Bantu Music from British East Africa and African Music from the French Colonies. The latter is far su- perior in quality and content, being drawn up under the guidance of the musicolo- gists of the Musée de l’Homme. The East African album, from Hugh Tracey’s recordings, is superficial and, one sus- pects, not truly representative, the selection having been made to please the ear rather than to present accurate docu- mentation. But Columbia also has a most exciting record—Olatunji’s Drum of Passion—in its general catalogue. Here is a Nigerian, Michael Olatunji, a highly competent musician who has lived many years in the United States. This record is a curious combination of his two worlds of music. The distinctive voice quality of the African male soloist con- trasts strangely with the painfully cultu- red Western chorus, in which the sopranos are consistently out of tune.

To hear something of the magical use of music, the listener should turn to some of the records of American Indians. The drum, the whistle, and the rattle are all magical weapons of the shaman, as is the chant. I single out two records here, both by Folkways. They are American Indians of the Southwest, and Sioux and Navajo Music. These are not only tech- nically excellent, but also contain fine music. Each is accompanied by a good descriptive text, forming an invaluable introduction by Dr. William Rhoads. The Sioux love song (side one, band 21b) is enchanting, and shows well how music is best made to suit the mood of the moment rather than to conform to theoretical niceties.

Folkways have four double albums—Music of the World’s Peoples—but these contain only snippets from their other albums, and there is some inaccuracy in the documentation. For instance, in volume four, band 51 is marked on the record label as “Tuni Forest Pygmies: Boy’s Circumcision.” The text mentions nothing about circumcision, but talks about Pygmy music in misleading gen- eralities. To complete the disaster, it is actually a Bangwana tribal version of a Nyamwezi song from Tanganyika.

The transition from the borderland of primitive music to that of folk music can perhaps best be made by listening to some Oriental music. Again, to start with the hardest, I would suggest listening to The Rise of an Empty City, a fine piece of Chinese folklore in the guise of opera. In this way historical fact is preserved in many parts of the world, and it is an experience to follow this particular drama, blow by blow, with the aid of the translated text. In a way, to listen thus is a great deal easier than to watch Chinese opera, with all its visual distractions.

If the listener’s interest in Oriental music is thoroughly whetted by now, he can move in a leisurely way through Indonesia with the aid of two Columbia records, Indonesian Music has as its main virtue, perhaps, written notes by one of the world’s foremost musicologists, Jaap Kunst. Then move on to a record that offers much better listening: Dancers of Bali. The beginner can easily detect a definite change of musical style, not occasioned solely by the distinctive gamelan orchestra. The difference is accounted for by the fact that Bali was once part of the old Javanese Hindu Empire, and still retains many cultural traits of Hindu heritage, particularly the music.

This brings us to an essential in the study of folk music, the music of India, which heavily influenced the Greek world in style and concept. Columbia has two good records. The first, Indian Folk Music, was recorded by Alain Danielon, Professor of Music at Harvard University. It presents many different styles of music, and the commentary is written in a lucid, if somewhat dry man- ner. The second is simply called The Sounds of India, and contains spoken
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1. N. Y. Times  
2. Christian Science Monitor  
3. Roger Tory Peterson

*commentary. This is an admirable record; the instrumentalists are among India's finest: Ravi Shankar plays the tabla drums, Chatur Lal accompanies him on the stringed tambura.

Following this, I recommend a particularly beautiful record, From the Lat of the Golden Fleece (Columbia). Produced in Greece with the Greek Folk Dances and Songs Society, this is an important and authentic document, and shows clearly how strong the Oriental tradition is in Greece, even today. Inside one, bond 6, there is an exquisite soprano solo, "Nonoruism," which illustrates the point as well as any.

If one wants to dally further with repetitive folk music, there is no dearth of records put out by all three companies; it is difficult to single out any for special mention. Westminster, however, has a detailed, competent, and enjoyable coverage of Spanish folk music (and Neapolitan, Hebrew, and Armenian). Columbia's The Folk Music of Southern Italy is one of its best, although one expects that certain effects are achieved for the listener's benefit. I prefer Waxways' documentary point of view. Take for instance, unashamedly present Rámenco Music of Andalasia, shorn off push-button glamour. There is no singing, with a good guitar, and no exciting dances on the second side.

In records of Western music, we can look for (and find to varying degrees) music still playing its various roles as accompaniment to manual labor, as means of passing and preserving history, or as a method of instilling moral values in the minds of the listeners and participants. But it is generally dissociated from religion. Yet this is an art historical dissociation, and it is not amiss to point out that a great many classics—indeed, these designed for sacred use—contain folk themes. Even more to the point we should acknowledge that the differentiation between sacred and secular music is also one that is largely a product of our own peculiar development.

In considering the role of music in religion, the Folkways religious music should be discussed. It covers religious music of various Christian sects, Jews, Moslems, Sufi, and Japanese Buddhist. It includes a documentation of Easter Day festivities in Jerusalem and of the Nazarene ceremony. All are worth listening to, but our appreciation of the latter peoples' music grows with understanding of their ways.

After returning toward home games via Westminster's The Armenian, we can appreciate even more the connection between music and religion and its use as a means of communication, when we listen to the Masses of J. S. Bach or to Mozart's Requiem. And at the risk of certain accusations.
may I suggest that the reader listen to Folkways' The Pygmies of the Ituri Forest, with notes by myself, telling how music is used in exactly this way—as a direct form of communication, even without words, between man and God. And this represents man at his most primitive!

But there is only one record with which to end this discussion. If I were to recommend one record above all others, it would be Columbia's extraordinary and exquisite recording, Arias, Anthems and Chorales of the American Moravians. This is the first in a series, "The Unknown Century of American Music," covering the period between 1760 and 1860. In my regrettable ignorance, this record was a total revelation, and one of my most exciting experiences in the world of recorded music.

The Moravians are, of course, of German descent. They have now been established in this country nearly 300 years. When they first came, they brought with them two things: a gentleness of nature that was manifest in religious tolerance at a time when such tolerance was not common, and a positive musical fanaticism. But the music they brought with them did not just stagnate, nor did it retain purely German in character. For the Moravians, music was, and still is, the living thing it was to earliest man. and so it lived and grew with them, enriching their lives and now, thanks to Columbia, waiting to enrich those of others. It has all the magnificence of Bach, with much the same degree of depth and sincerity; and it has overtones that are almost Italian, abounding in youthfulness and vigor. Yet in character it is part of the American heritage.

The brasses, strings, woodwinds, and organ combine with the choir to give a near perfect performance of this very lovely music, and the essence of this beauty lies in the fact that the Moravians recognize what our ancestors did—and what primitive man still does—that between the sacred and the secular the line is artificial and arbitrary, and that music is one of the surest ways of uniting the two into a single whole. The Moravian attitude is summed up best in a story quoted on the record's jacket:

A New England divine questioned a Moravian youth, following a Saturday concert (which seems to have been almost as obligatory to Moravians as Sunday Church), as to whether he would use the same instrument in the divine service of the morrow that he used in the profane concert of the day. The serious-minded young Moravian, not seeing his life divided in this way, replied with another question: "And shall you, sir, pray with the same mouth tomorrow with which you are now eating sausages?"

Suggested Listening List:

**TINIC MUSIC**

**COLUMBIA:**
- KL205 African Music from the French Colonies
- KL213 Bantu Music from British East Africa

**FOKWAYS:**
- FE4441 Drums of the Yoruba of Nigeria
- FE4470 Tuareg Music of the Southern Sahara
- FE4477 The Topoke People of the Congo
- FE4462 Wolof Music of Senegal
- FE4420 American Indians of the Southwest
- FE4101 Sioux and Navajo Music

**FE4504-7 Music of the World's Peoples**

**RECORDER AND EXTERIORIZED FORMS**

**ALMAY:**
- CL1112 Olatunji's Drums of Passion

**O.K. MUSIC:**
- FE4356 Traditional Dances of Japan
- FE417-8 Negro Music of Alabama
- FE4137 Flamenco Music of Andalucia
- FW2202 The Rise of an Empty City

**AMERICA:**
- KL210 Indonesian Music
- KL5174 The Folk Music of Southern Italy
- KL305 Indian Folk Music
- ML4608 Dancers of Bali
- WL119 The Sounds of India
- WL123 From the Land of the Golden Fleece

**WESTMINSTER:**
- WF12001-5 Songs and Dances
- WF12018-23 of Spain (11 volumes)
- WF12011 Folk Dances from Spain
- WF12013 Folk Dances from Armenia
- WP6012 Neapolitan Folk Songs
- XWN18728 Hebrew and Yiddish Songs
- XWN18080 Spirituals: The Tuskegee Institute Choir
- WST15029 Spirituals: Graham Jackson Choir

**RELIGIOUS MUSIC**

**FOKWAYS:**
- FE4457 The Pygmies of the Ituri Forest
- FR8943 Islamic Liturgy Songs
- FR8951 Easter in Jerusalem
- FR8975 Mushroom Ceremony of the Mazace Indians
- FR8990 The Way of the Echiji (Zen Buddhist Ceremony)

**WESTMINSTER:**
- XWN18726 The Armenian Mass

**COLUMBIA:**
- ML5427 Arias, Anthems and Chorales of the American Moravians
Dredge down! The gears of the bow winch mesh; the great spool turns, and the steel cable pays out as the biological dredge is lowered into the tropical sea. Fifty fathoms below is a submerged, flat-topped mountain, the Gorda bank. We are here to seek what lives on that submarine butte.

So it was, twenty years ago, when the research vessel Velero III was exploring the strange biota of the Gulf of California. I was, as a fledgling marine botanist, witnessing dredging from a ship for the first time in my career. We were over the bank, and now were blindly scraping off a bit of its surface to bring to light the creatures of the dim sea floor, almost at the uttermost limits of light.

The dredge came up full. Its great bag-load, bulging within a protective chain skirt, was poised for a moment over the sorting screens. The closing cord was cut, and out poured a pile of shiny nodular pebbles, each an inch or two in diameter. But these were strange stones indeed, covered with warts and knobs, and all of a rose-pink color. In fact, there was not a stone in the lot. This was a dredge load of plants—stone plants of the sea, calcareous red algae known collectively as nullipores.

In the days of lace cuffs and powdered hair, these curious plants were generally considered to be some sort of inorganic, stalactite-like form, and found their way into "collector's cabinets" of the time along with coral tubes, worm tubes, walrus tusks, and other novelties of the sea. Linnaeus tried to classify them as coral-like animal forms indeed. Lamarck coined their name nullipore—to distinguish these "without visible pores" from the other
as corals. It was not until 1837 that
corals were finally and positively
cognized as once-growing plants.

Today we recognize calcareous
slate in each of the three major
cups of marine algae—the green
chlorophyceae, the brown Phaeophy-
aceae, and the red Rhodophyceae.
Among the green algae, calcified
slate occur only in a few families,
typical confined to warm seas. Indeed,
atively few genera and species of
green algae are calcareous. Nonethe-
ise, in their tropical habitats these
plants are often remarkably abundant,
sometimes are among the most
notorious members of the local mar-
cine community. Thus, on some of the
nearly shelving, intertidal flats of Okin-
wa, one wades ankle deep in a ver-
viable meadow of Acetabularia—seen
on an acre of almost pure stands of
remarkably beautiful little green
rucks. In the sandy bays of Cuba,
Bahamas, and south Florida, one
sees an abundance of the strange Nep-
olic Shaving Brush (Penicillus), the

Air view of Marshall Island atoll. 
above, shows surf on reef’s algal rims
and tiny islets built upon the reef flat.

Nullipore fragment, below, typifies
one of the many kinds of stony plants
that grow on seaward margins of reefs.
Bossiella, with segments of wingnut shape, is found in California coastal waters.

Corallina polysticha is a rare, jointed red alga from Guadalupe Island, Mexico.

Lithothrix, a red alga of the northeast Pacific, has unusually short segments.

Galaxaura acuminata, a non-segmented red alga, is a tropical Pacific species.
little Christmas-tree-like *Rhipocephalus*, and the delicate green, fanlike *Udotea*. Among the coral heads and rubble flats on the bottoms of the vast atoll lagoons of Kwajalein or Eniwetok, mounds and mats of *Halimeda* grow in such persistent plenty that the lagoon floor sediments are largely built up of the accumulated fragments of these jointed plants.

Then there are the strangely and intricately fashioned species of the family Dasycladaceae: *Dasycladus*, *Sornetella*, and *Neomeris*. These are tiny little plants, often inconspicuous, but sometimes the most striking members of an undersea flora. I remember living one day in a warm island lagoon in the Gulf of California and being impressed by great, round boulders on the bottom that were studed with little, glistening, upended "worms" of a brilliant emerald color— the green alga *Neomeris*. Many members of this family are known from the fossil record; they are thought to have contributed to the formation of limestone rocks.

Among the brown algae, calcareous species are few, and confined largely to the tropical genus *Padina*, whose interesting, fan-shaped representatives may be found in almost all warm seas. *Padina* commonly has concentric rings of superficial calcium carbonate, alternating with bands of delicate brown-brown hairs; underwater, they sometimes stand out as the most gracefully formed and artfully patterned plants of the sea floor.

In red algae, as in the other two groups, the occurrence of calcified forms is limited to a few families. But, here, one of these families—the Corallinaeaceae—is of wide distribution. The only other important calcareous genus of red algae are *Gelisosa*, *Liastra*, and *Peyssonnelia*. These occur mostly in the Tropics, but are seldom abundant or conspicuous.

Thus, the Corallinaeaceae includes the overwhelming majority of the calcareous plants of the world. They occur from the Arctic to the Antarctic and from the highest and most inhospitable intertidal levels to the cold, dim depths of ocean at the extreme limit of light penetration. Sometimes a score of species may live in a single habitat, again, one species may dominate a region to the near exclusion of other forms of vegetable life.

Despite the rigidity and often brittle...
character of many calcareous algae, the structural differences from the usual, fleshy forms are essentially eliminated by the application of a few drops of hydrochloric acid. Removal of the carbonate reveals the typical cellular structure of the plant, hitherto obscured by encrustation.

The stony material laid down by the living cells of the plants is largely calcium carbonate. This takes the form of calcite in the Corallinaceae and of aragonite in the other red algae, although some magnesium carbonate is present. While the encrustation first appears in pectin-bearing layers of the cell walls and then extends into the cellulose layers, the living protoplast of the cell always remains enveloped by an uncalcified membrane.

In the segmented corallines, some groups of cells remain completely uncalcified, thus forming flexible joints between rigid segments. Such a delicate, erect, bushy plant as Corallina is admirably suited to surf shock and agitation—hardly less so than is the rigid, rock-encrusting Lithophyllum with which it may grow.

The calcareous red algae, like most of the members of this large plant phylum, fulfill their life history by means of an alternation of generations. That is to say, a given plant does not reproduce one of the same kind as itself. Instead, it gives rise to a different generation of plants, and these, in their turn, repeat the first generation. These generations are of two kinds: one is sexual, and consists of separate male and female plants. The other is non-sexual, producing spores that germinate to grow into sexual plants.

At maturity, the non-sexual plants form small, domed cavities on their exterior surfaces. These asexual conceptacles produce small, red structures consisting of four spores in a row (tetraspores). The spores are released into the water by means of one or more exit pores from the cavity. The released spores then settle down, germinate, and grow into new plants. Some grow into male and some into female plants which, except for reproductive details, look very much alike.

The male plants produce quite small conceptacles in which are formed exceedingly minute, non-motile, male cells (spermatia). These, usually only 2/1000 of a millimeter in diameter, are released into the water through a single pore in the conceptacle roof. Meanwhile, the female plants have produced much larger conceptacles on the floors of which stand many receptive organs called carpogonia (C, above). Meanwhile, the conceptacle of male plant, below, discharges non-motile spermatia (D).

By what mechanism the drifting but non-motile male cell enters the tiny pore of the female conceptacle to accomplish the sexual union we do not know. When a spermatia makes contact with a trichogyne, however, its nucleus enters the carpogonium, effecting sexual fusion, and begins the development of a new generation. Strangely, this new generation remains as a distinct parasitic plant within the female plant. There it grows into a small mass of cells, and produces a special group of spores into which the male cell entered—into sea water outside. There it finds...
trichogyne—sensitive, tubular, hairlike extension (E)—forms on each carposporangium in female conceptacle, above, readying it for fertilization. In fertilized female cell, below, early stage in carposporangium (F) development is seen.

Calcareaous members of the red algal family Corallinaceae are the most prevalent form of the stone plants, so widely distributed that they form part of the marine flora of every maritime nation of the world. In the glacial fiords of Norway or Greenland, one finds thriving beds of nullipores. Crustose corallines cover wave-beaten rocks from Kamchatka to Chile, and from Newfoundland to Kerguelen. Delicate, hairlike forms live on the leaves of little grass in Cuba, and on eel-grass in Japan. The jointed mossiellas dwell less successfully in the cold, clean ponds of Vancouver Island than beside sewer outfalls in southern California. The dainty junias are equally prominent in spongy, algal turfs on the reef flats of East Africa and in lagoons of Micronesia. Despite the ubiquity of these plants, they have been little studied and remain among the least known organisms of the sea.

Since plant scientists have generally neglected the calcareaous algae, their importance in many natural phenomena has been little recognized. This is particularly true of one of the most extraordinary of all marine geological phenomena—the tropical "coral" atoll. The story of the calcareaous algae’s contribution to the formation and growth of the atoll is so remarkable and so little known that it seems particularly appropriate to tell something of it here.

During the last century, a number of naturalists made visits to the coral reefs of the Indo-Pacific region and, from their observations, theories of atoll origin and growth were developed (Natural History, March and April, 1859), Charles Darwin, James G. Dana, Sir John Murray, Alexander Agassiz, Reginald A. Daly, and others interpreted the atoll from a geological or zoological standpoint. But each investigator failed in every instance fully to recognize the importance of calcareaous algae as controllers of reef development. It was not until Sir Edgeworth David’s South Pacific expedition (1906-1909) that evidence was obtained to establish the significance of plants in this relationship. Since then only an occasional marine botanist has written on the subject and expanded the knowledge of the role algae play in atoll formation. As a result, some long-standing and widespread misconceptions are still prevalent.

Some of the pertinent facts are:

First, nullipores have been found to be among the principal components of atoll reefs in a great majority of cases. In some instances, they are almost the only visible components, to the virtual exclusion of coral animals.

Second, the principal cementing agent in the reefs is the nullipore. Third, calcareaous algae have been found actively working at depths of six hundred feet.

Fourth, the seaward margins of actively growing atoll reefs are often covered by a pavement-like growth of Porolithon, a species of nullipore.

Fifth, borings to depths of several thousand feet indicate the consistent presence of great quantities of nullipore material throughout the reefs.

The most striking first impression of many atolls is of their enormous size. Tens of thousands of service men have visited the vast lagoons of Kwajalein or Eniwetok, thirty miles or more across, surrounded by dots and lines of vegetation-clad islets. But these atolls have not always been so large. They grew, and are still growing.
Tongatitu, in the South Pacific, is an example of combined building action of coral animals and the calcareous algae.

Elevated margin of the seaward reef on Majuro Atoll in the Marshall Islands, below, is almost totally made of red algae.
One also finds small atolls, such as Palmyra in the Line Group, and nearby reefs, such as Kingman, that barely break the surface of the water. All of these are related within the atoll phenomenon. To understand an atoll’s development, it must be considered as a kind of dynamic, living organism. It is, really, a vastly complex association of living things, all dwelling together in a marvelous balance, each plant and animal contributing to the life and growth of the whole atoll and to the delicate balance maintained between construction and destruction.

As a possible point of departure in the development of an atoll, consider a reef such as Kingman, consisting of an association of coral animals and coralline algae, growing on a lightly submerged sea mount. Let us say that the reef is five acres in extent and barely breaks the surface at low tide. Now, somewhat different optimum growth and persistence exist among the corals and the nullipores with regard to the surf that breaks over the reef. The rigid, branched, little corals tend to break and fragment under severe wave action. But the massive, reef-forming nullipores are unaffected by the pounding surf. In fact, the stronger the surf the better they grow, for one of the principal factors for their growth is the availability of oxygen for their respiration during the dark hours of the night, when their photosynthetic pigments are inactive. Accordingly, on this five-acre reef, the first organisms to grow above the water surface, creating a condition of light, will also create conditions that tend to favor the growth of the nullipores and to reduce the upward extension of the coral. Herein begins the formation of an atoll from a reef, for the nullipores grow into the breaking surf. As they do so, the intensity of the surf becomes greatest around the margins of the reef. Here the nullipores grow upward and form a rim slightly above sea level. This rim, which breaks the impact of the waves on all sides, provides a relative calm over the inner part of the reef. If the sea level is rising, or the sea floor subsiding, a lagoon develops within the slightly elevated ridge, aided by the destructive process of solution resulting from the union of carbonic acid derived from a respiratory carbon dioxide produced by the life of the lagoon.

The rate of outward growth of the recently discovered calcareous alga *Lithophyllum reesei*, found on the west coast of Mexico. Shapes of algae are nearly as numerous as are species.
reef margin reflects differences in surf and in available growth nutrients, due to wind and currents. As a result, the young, dynamic atoll usually takes on a somewhat elliptical shape.

Reef margins are extended seaward in three ways: by the growth and cementing action of the nullipores, by the often profuse growth of corals on the outer front, or face, of the reef below the surf zone, and by the infinitely slow build-up of a vast talus slope of nullipore and coral fragments to the abyssal sea floor. Whenever the reef ridge dissolves down to a level that permits the sea waves to pour in over it, the increased supply of oxygen for nighttime respiration encourages the growth of the pavement algae by which it is built up again.

The seaward advance of the nullipore ridge, whose height above sea level is controlled by desiccation, leaves behind it a reef flat that stretches between the ridge and the central lagoon. Storms cast up boulders and debris from the reef margin and the talus slope onto this reef flat.

Until such a pile of sand and rubble appears on the reef flat, all rain water is dissipated into the open sea. With sufficient material to confine it, however, the fresh rain water stands in the sand at sea level, floating on the salt water below it, and mixing only very slowly. As a pool of fresh water forms in the sand, seeds (carried to the islet by wind and sea) sprout and penetrate to the water supply, and thus the island vegetation comes into being. Sea birds come: as they feed on the fish of the reefs and lagoon, and nest in the vegetation, they convert animal life of the sea into fertilizer for the land. The birds thrive, trees and shrubs grow, and gradually humus forms on what at first was only barren sand and rock.

In all of this islet growth, the calcareous algae play an important role, spreading their crusts over the rubble and the sand, cementing and binding the reef margin, and advancing—ever so slowly, but steadily—into the waves.
THE AMERICAN BALD EAGLE

Despite protection, this wary bird cannot co-exist with man

By George Heinzman

ALTHOUGH the American bald eagle, Haliaeetus leucocephalus, became our national emblem 179 years ago, the bird has received little protection until recently and is now greatly reduced in numbers. Alaska and Florida are the principal strongholds of a range that once included virtually every state. Even in Florida, of an estimated 500 active nests a few years ago, some observers believe that only 50 are occupied at present.

While studying nest sites in Florida, I learned that the bald eagle is un-shy despite its legal protection. In an invisible circle, with a radius of 50 to 300 yards, seems to exist around nests observed. Outside the perimeter of this circle, I could observe and photograph the birds openly without unduly disturbing them. Three steps inside it, and they flew, making their squeaking cry of alarm.

Eagles mate for life and are devoted to “family” matters at least half the year. The eyrie is a mass of limbs, twigs, moss, and grass, high in a pine, mangrove, or cypress tree. Most nests are four to eight feet in diameter and deep. Used for years, they may become tremendous. Charles Broley, Florida’s famous eagle bander, reported a record eyrie that was twenty feet deep and nine feet in diameter.

Nesting starts in Florida from September to November. Adults refurbish the eyrie for roughly a month before depositing one to three eggs. They incubate about thirty-five days. The young are covered with light down that is replaced in three weeks by heavy gray “wool.” From the fifth to eighth week, they acquire their plumage, which shows only scattered lighter shading until the fourth year, when the maturing birds attain their white head and tail.

Florida nests rarely contain more than two eggs, with an average of about 1.5 birds fledged per nest. One nesting usually dominates the peck

Perched on a limb to left of its nest, above, eagle assumes watchful stance.

Alert position is maintained, below, although eagle has shifted to a higher perch. Male bald eagle is warier than the female, is first to flee if approached.
order and receives the most food and attention. Often the second nestling dies of neglect and abuse.

Eaglets use the eyrie for practice flights—flapping hops into the wind—and make their first successful flight about the twelfth week. This usually occurs from February to April. I have seen parent birds entice the young to try their wings by approaching the nest with a fish, then veering off, until the young take to the air. The parents stay near the nest, feeding the young, for perhaps a month more.

During the summer many eagles go north, even as far as Canada. However, evidence uncovered by Dr. William B. Robertson, a Park Service research biologist in the Everglades, shows that not all eagles wander. Some stay in Florida all year, usually living away from the nest in summer.

Depending on the availability of other food, fish constitute 65 to 90 per cent of the eagle's diet. This is supplemented by snakes, wounded waterfowl, carrion, and small mammals. An adult eagle weighs eight to twelve pounds and has a six- to eight-foot wingspread. The male is slightly smaller than the female, but the difference is apparent only when they are seen together. He is also warier, being the first to fly if approached. Tests show that captive eagles can carry about five pounds, but wild ones may be able to lift twice as much.

The Audubon Society is attempting a nationwide census to determine reasons for the eagle's decline and to countermeasures to be taken. Dr. Robertson, making a long-term study of Everglades National Park, has been watching about 60 nests. He suspects much of the eagle's observed failure to reproduce in certain parts of Florida may be caused by natural sterilization owing to age, by the tendency of many eagles to "vacation" from family-raising for a year or so, and by human disturbances during incubation and nesting. My observations of 35 central Florida nests support the idea. Remote nest-rearing was 65 per cent successful, compared to 6 per cent for nests near human activities.
Mr. Heinwman's report on the bald eagle is based both on research and extensive observations in the field, where he made the photos seen here.

The bald eagle has somewhat specialized environmental needs—good fishing water, and tall, sturdy trees with solid crotches to support nests that may weigh hundreds of pounds. Man has altered the eagle's environment drastically by cutting most tall timber and draining much fishing water. Throughout Florida, towns have been built beside inlets and bays around inland lakes, depriving the eagle of thousands of square miles of fishing water, since the bird has not learned to co-exist with man. Individuals may remain in an area a few years after man's intrusion, for the birds seem doggedly determined to return to old nest sites. But their productive days are over: man's activity near a nest prevents giving the young the protection needed for successful rearing.

Nature dealt a severe blow, too, in 1940 when hurricane Donna lashed Florida in early September. Observations by plane, Dr. Robertson found 90 percent of the eagle nests destroyed in the Florida Bay section of Everglades National Park. Other parts of the state were less damaged. My observations show about a 30 per cent reduction in central Florida. By December, Dr. Robertson found rebuilding at two-thirds of the destroyed nests, but a rate analysis of long-term damage is impossible. For comparison, in a mid-October hurricane in 1944, they reported that 64 of 65 destroyed nests were rebuilt. But in only one third of the nests were young successfully the first year, as compared with 70 per cent success the year before. Donna, hopefully, may have had a lesser effect.

What lies in the future? Most of Florida will go the way of the nation. Some breeding stock will remain in mate parts, but the species will be dangerously near the point at which living birds will be so few that reproductive failure due to inbreeding, sterility, and reduction of the survivors, plus other partial factors—replenishment is impossible. The American eagle's last hope south of Alaska is to be in the Everglades National Park in central Florida cattle-lands, the ranchers—proud of their avian assets—protect them scrupulously.
Baluchistan Find
Ruins of a 4,000-year-old culture still stand in West Pakistan

By Walter A. Fairservis, Jr.

Few places remain in the world where the archeologist can encounter formerly unknown ruins of enormous extent. Nineteenth- and early twentieth-century travelers are replete with wonderful stories telling of the discovery of Xinal, Dacchu Picchu, Petra, and Angkor Wat. But today, aided by aircraft and automobiles, archeologists have filled most blank sections of the earth’s maps so far as spectacular surface ruins are concerned. It is remarkable, therefore, that in the winter of 1959-1960 in the district of Las Bela in West Pakistan an American Museum of Natural History party encountered, ritually intact, previously unknown settlements that date from the second millennium before the Christian era.

For approximately eight miles in its region, the stone walls of ancient buildings can be traced without putting a shovel in the ground. So well preserved are some of the ruins that we can walk along ancient streets that are flanked by buildings, the walls of which frequently rise above our feet. There are steps leading onto structures, and occasionally a lived ramp indicates an ascent into a normal building. Scattered about are fragments of pottery that help to date the ruins; and sometimes one discovers bangles, animal figurines, and bits and pieces of alabaster vessels—all of which are evidence of an origin in more antiquity.

The discovery lies in the northernmost portion of the wedge-shaped district of Las Bela. The widest part of the wedge is a stretch of the Arabian coast just west of Karachi. The narrowest portion extends a finger of land into the southeastern portion of the Iranian Plateau, here called Baluchistan. The district is thus surrounded by mountains on all sides but the south. The apex of the wedge is gathered in the valley of the Porali River, which drains southward out of the mountains of Baluchistan. It is one of the few perennial streams in the entire region to the west of the Indus River Valley, and the delight of its waters is enhanced by contrast to the desolate surroundings. The capital of Las Bela is Bela, a small town close to the Porali River, about two miles south of the site of the discovery. Bela retains much of its ancient aspect. This is a town with palaces, mosques, high-walled houses, and a fine, covered bazaar. It is situated in the midst of a ten-mile square of intensely cultivated land that provides a lovely setting of old trees, broad fields of mustard and of grain, and fine date palms. Nowhere else in all Baluchistan are the cattle so fat and healthy.

People have been drawn to this region because it is one of the few widely cultivable areas in Baluchistan. To the west the mountain wall is broken by the Jhan Pass—one of the most important in the Indo-Iranian borderlands. Through this pass Alexander marched his men on their return from India. Much later, during the eighth century A.D., Arab armies under Mohammed Ben Kasim moved through the pass from the west. These armies eventually conquered Sind and thus began the Moslem impact on India. Haroun, one of Kasim’s generals, has a tomb at Bela—a lonely reminder of this important period in Indian history. In 1838, a British naval officer, Commander T. E. Carless, explored some of the canyons found in the mountains north of the cultivated area. In one of these he came upon a large number of artificial caves cut into the cliffs. Many of the caves had doorways and steps, and within were niches (presumably for lamps) and small storage areas. Carless’ description of the strange caves was the only one until the great Asian explorer Sir Aurel Stein visited them in 1942. Stein also found several pre-
A narrow street between buildings is viewed by expedition members, below.

Ancient settlement at left, above, is same one shown on p. 22. At right are "temple" mounds. In the background, beyond trees, is Porali River Valley.

Historic sites in the area. Unfortunately he died before a report could be prepared for publication.

Thus, for a number of reasons, Las Bela district has been worth archaeological investigation. These reasons are emphasized further by Las Bela's geographical situation just west of the Indus Valley, on one of the high roads between the Near East and India along which the ideas and traits of earliest civilization had come. Previous archeological work in Baluchistan has indicated that in prehistoric times these areas were occupied by primitive farmers who came from Iran, probably first in the late 3rd millennium b.c. Later, farming villages became more numerous as populations grew, and control of the soil for agriculture became firmer. By 2000 B.C. these village cultures had become quite elaborate and apparently had had a formal religion, with monumental temples amid village homes.

Most stages in this development have their equivalent in prehistoric Iran, to the west. They indicate a steady pulsation of new ideas and ex-
haps new people moving eastward over a period of some 1,500 years. The Iranian influences did not stop in Baluchistan, however, but moved on, penetrating into the Indus Valley.

On the rich alluvium of the Indus came a parallel development, the earlier stages of which still escape the archeologist’s spade. Later stages, however, are illustrated by the world-famous Harappan civilization, third of the great civilizations of ancient times. This civilization has been known since the 1920’s, principally because of the excavation of two of its largest cities: Mohenjo-daro, in Sind, and Harappa, in Punjab—both

White stones, above, 8 to 10 inches high, are part of large ring. Similar stones form avenues and circles, below, among Edith Shahr Complex B remains.
part of West Pakistan now. Town planning, drainage systems, fired brick, and cotton cultivation are some of the contributions to man’s advancement made by this remote civilization. Most people of the Harappan civilization lived in villages that clustered round urban centers—the hubs of their ceremonial life. This contrasts with the life of the Sumerians, their nearest civilized neighbors. Most of the Sumerian people lived in cities, few in villages. Obviously the pattern of living was drastically different between these civilizations. The Sumerian civilization tended to be more dynamic and unstable; the Harappan, in its more rural setting, more durable and calmer. In this sense, at least, we have a fundamental division of early civilization that seems to presage the essential differences between East and West that have been so overcelebrated by writers in modern times.

Unquestionably, the idea of civilization came from the ancient Near East to the Indus Valley. In fact, a number of authorities have pointed out exact parallels among such characteristics as architecture, seal form, certain crafts, and very probably the hierarchical government. Harappan civilization is nonetheless overwhelmingly Indian in character and quite distinct from its nearest civilized equivalent in Mesopotamia.

Obviously something had happened to civilization both in its journey eastward and in its development in an Indian setting. At this point in our researches we know little of these factors. The discoveries in Las Bela are, therefore, of more than a little importance, for they represent the development of a settlement whose density of population and architectural accomplishment approach—if they did not actually achieve—urbanization. This concentration of men and resources in one of the areas outside the classic river valleys of early civilization is extraordinary. One might well ask what criteria one can employ to decide what constitutes civilization and what does not. These new discoveries give some answers to such queries.

On New Year’s eve of 1959, the writer, in company with Dr. and Mrs. Sherman Minton, traveled from Karachi to Las Bela to investigate the caves reported by Carless in the 1830’s. Dr. Minton is a research associate of the American Museum in herpetology, and it was with more than casual interest that we entered an area so little known to both our scientific fields. En route to the caves, which are located in the Kud River area, we had to cross the Porali Valley where that river enters the broad, cultivated plains. On the west bank of the valley our path crossed close to enormous heaps of large boulders, some of them thirty feet high. These boulder “hills” blended with the boulder conglomerate slopes of the mountain beyond, and seemed at first to be a part of that landscape. However, close scrutiny revealed that these rock heaps were distinctly separate from the mountains and were, in effect, artificial. The briefest examination at the foot of these boulder hills produced a variety of potsherds that gave proof of the place’s having been inhabited by man in late prehistoric time.

On the following day we visited this site again and more surprises were forthcoming. Beyond the stone heaps that stood on the east of the site, close to the mountain slopes, was a series of generally rectangular structures made of boulders laid in tiers. These structures were arranged parallel to one another so that a network of narrow “streets” was formed between them.

The structures are all some 15 to 20 feet wide and usually between 70 and 100 feet long. There are indications that they were compartmented, as rock steps led up into these “rooms” from the streets. It is very likely that there was a mud brick superstructure on these stone foundations that long since disappeared (see the reconstruction on these pages).

Investigation of the boulder hills showed that they were the remnants of monumental buildings. They had been constructed in receding stages, ziggurat fashion, topped by small building made of mud or fired brick. Ascent had been made by steps and ramps. In one case there was evidence of a stone drain that had been used to carry water from the top of the structure. This use of drains paralleled in other parts of Baluchistan and at the great site of the Harappan civilization, Mohenjo-daro. At the latter place, a great bath, obvious for ritual purposes, occurs on a high portion of the site. The water could be let out through a drain.
similar drain system occurs in a structure—probably contemporary—found in the Quetta Valley in northern Baluchistan. These monumental buildings, then, were probably temples.

Another interesting structure was an enormous rectangle just east of the main mounds. This structure is more than 200 feet long and about 40 feet wide. There are traces of at least eight entrances, which suggest that the building was some kind of communal hall—perhaps a dormitory.

The discovery of bull figurines, clay models, incised and painted pottery, and other such artifacts proves that this site belonged to a well-known prehistoric culture of Baluchistan called the Kulli culture. This culture, in its latest phases, was contemporaneous with the civilization of the Indus Valley. Indeed, there was evidence at this site to reaffirm this dating.

The elaborate stone construction and the formal layout indicate that this site, known locally as Edith Shahr, was probably used for ceremonial purposes and was not merely a farming village. This opinion is confirmed further by the fact that Edith Shahr turned out to be only the south-

Major buildings at the Edith Shahr site, seen in artist's reconstruction, above, were probably temples. Women, below, typify villagers of this period.
ceremonial. was The contributions community interesting. of structures Baluchistan. culivable ing.

The ley building, -then point-buildings, those at Edith Shahr. Beyond these structures were located the settlements of those who had used the “temples.”

These remains of late prehistoric time, which we now call the Edith Shahr Complex, are extraordinarily interesting. Unquestionably they are evidence for the existence of a specialized populace—very probably a priest community that had to be supported by the prehistoric farmers who lived in the fertile area to the south. Other contributions may have come from traders who had to pass along the valley the sites command. Perhaps a place of so many temples may have been a sacred center—a goal of pilgrimage. The rectangular structures with their parallel streets may not even have been habitations for the living. A few fragments of possibly human bone that were found on their surfaces indicate that they may have fulfilled the function of tombs.

The formal aspect of these ruins, their dominant position in the valley, their great number, and their impractical separation from areas of good, cultivable soil all seem to point to a ceremonial cult of extraordinary vitality. If these Edith Shahr sites represent a ceremonial complex—and every indication so far is that they do—then we have a clear division between the secular and the sacred that is of considerable significance to the systematic study of civilization.

In every instance but one we have reason to call the Kulli culture a civilization. We have monumental building, hierarchical government, specialization, and even evidence of wheeled vehicles. Only writing is absent from our list. Perhaps this too will be found by future excavation and the Kulli culture will become the Kulli civilization.

Our archeological survey was replete with surprises. There was evidence here and there that the Kulli culture had met a violent end. Indications of burning at the top of some high temple mounds suggest that a conflagration had occurred. On the slope of the mountain that ran behind the first Edith Shahr site, a stone circle was found. It measured some thirty feet in diameter with a wall—more than four feet thick—standing some three feet high. The wall was broken in its eastern side by a narrow entrance. Within the circle we found strange, heavy pottery decorated with coarse, appliqué loops and bands—completely alien to the fine prehistoric pottery of the Kulli culture. This was our first inkling of surprises to come.

The New Year’s eve that we had trekked to the caves had been a difficult one. During our return to camp, night fell and we were forced to walk over rough ground in darkness. Our route led over the back of the mountain whose slopes were behind the first Edith Shahr site. Unable to find a trail, we did considerable stumbling and falling over numerous boulders—a particularly trying hazard. Need- less to say, for Dr. and Mrs. Minton and myself, it was a memorable New Year’s celebration. It was not until a month later, when I was able to undertake a careful survey of the region in co-operation with the Government of Pakistan’s Department of Archeology, that the probable cause of some of our stumbling was revealed. On the mountain slopes that led down to the fertile plains southwest of the first Edith Shahr site was an enormous complex of stone structures through which we had wandered blindly. From the top of the slope overlooking the Porali Valley the remnants of a great stone wall run down the mountainside for more than 2,600 feet. It terminates in the midst of more than 100 structures of different character. Here are stone circles like that previously described. But also there are stone circles made of double rows of white stones, in the midst of which stands a larger stone—like a menhir in Western Europe. There are long “avenues,” outlined with white stones, ending in clusters of the same material. These avenues lie along an east-west axis. There are large buildings—square and rectangular—divided into compartments; there are clusters of rectangular structures like those of the Kulli sites. One of these structures is enormous, some 240 feet long.

At the time of the discovery I had with me David Henemeier, an Eagle Scout from Karachi. Despite both our efforts, it was impossible to survey this immense complex without help. Even more vexing was the fact that as we worked up the Porali Valley from that point—on either side of the river and close to the Kulli sites—we found more of these same ruins, with pottery and other artifacts identical to that of the stone circle first encountered. Even after several trips, the discoveries did not end, it was not until we obtained the use of a helicopter that boon to modern archeology, that we were able to trace the apparent end of this site (which we call Complex B of Edith Shahr). I say apparent because, on the last day of flight we came across a site with more buildings than any of the others!

The true meaning of these finds escapes us for the moment. There seems little doubt that they represent an invading group, perhaps related to those groups that created the megalithic structures of South India and Western Iran. These ruins dominate the old Kulli culture sites and over look the entire valley. We found their traces at the entrance of passes leading east and west. Undeniably they represent a powerful people. But we cannot yet identify these people, nor are we at all certain what the Complex B ruins really are. Are they ceremonial centers, with solar worship the dominant theme? Are the tombs among them, as fragments of a human bone suggest? Are some of them palaces where kings gave orders to a peasant populace spread out over the fertile plain?

There are a host of questions at few answers, at least until such time as our shovels probe the earth and around those ancient walls. For the moment, we are shedding little light indeed on an extremely important problem in mankind’s history. But at least there is some light...
Early culture pottery

Later culture, perhaps made by invaders

Parts of clay bangles

Early culture pottery

Brahma bull figurine

Part of a model cart
Modern researchers have identified many Old Testament plants

How did the Holy Land look during the days of Abraham and Moses, Solomon and Isaiah, Ruth and Esther? How did the people live; what did they wear; what was their food? An amazing number of clues can be found in a study of the plants mentioned in the Bible.

The land that gave rise and sustenance to three religions — Judaism, Christianity, and Islam — is only about the size of New Jersey, but the diversity of its landscape is remarkable. To go down to Jericho from Jerusalem, in the rugged Judean mountains, is to drop 3,000 feet in only fifteen miles, moving abruptly from a temperate climate to tropical heat. The River Jordan flows into the Dead Sea at 1,275 feet below sea level, while, at the northern end of the Jordan Valley, the heights of Mt. Hermon and Mt. Lebanon are forever capped with snow. Extending from the borders of the Mediterranean to the foothills of the mountains are three valleys — the Plain of Sharon, the Plain of Esdraelon, and the Valley of Elah. These alone are rich, subtropical areas of agriculture — the “land of milk and honey.” The rest of the region is rugged mountain or bleak desert.

This is a land of contrasts. From May to October, the sun beats down without interruption. Streams dry up, and vegetation is sparse, supported only by heavy morning dew. The “early rains” of October and November break the summer drought and soften the land for plowing. In December, January, and February, the rains beat down. The “later rains” of March and April give the crops their last bit of water before the dry season sets in. These diverse geographical and climatic features have produced a corresponding variety of animal and plant life.

In early Biblical times, life was seminomadic, halfway between that of desert Bedouin and settled farmer. We read of Isaac sowing, Joseph binding sheaves, and Reuben in the harvest field. The seminomads gathered olives, dates, walnuts, pistachios, and figs. When they began to form villages and towns, they grew barley, wheat, spelt, millet, sorghum, flax, grapes, apricots, various vegetables, and herbs.

Bread, the staple food, was baked daily; sometimes olive oil was added to the dough.
Wafers were baked, flavored with honey. Cakes were sprinkled with aromatic herbs. Since water was scarce, goats and sheep provided milk for drinking and for making cheese and butter.

In addition to bread and milk, the ordinary diet consisted mainly of vegetables such as cucumbers, broad beans, leeks, onions, and garlic. There were soups of lentils and beans. On rare occasions, meats were eaten, flavored and preserved by a variety of spices. Standard foods for soldiers, travelers, and field workers were raisins and parched grain.

For dessert there were fruits: fresh and dried figs and grapes, apricots (the “apple” of the Bible), melons, and pomegranates. Pistachios, almonds, and walnuts were relished. Wine was universal: other alcoholic beverages were made from dates and pomegranates. Pomegranates also provided the base for several non-alcoholic drinks, as did the licorice root.

During their wanderings in the wilderness, the Israelites probably lived largely on manna, which, even today, is a favorite confection in many Eastern lands. Manna is a sap or gum exuded from a variety of plants, including alhagi (Sinai manna), tamarisk, flowering ash, Lecanora lichen, and the tiny alga Nostoc. It also results from the actions of scale insects, which suck up saps of various plants and then secrete drops of fluid that dry into sticky, sweet-tasting solids on the body of the host plant.

For cooking of all kinds, for drugs, cosmetics, perfumes, and dyes, people of the Biblical lands again turned to herbs and trees. Aromatic coriander leaves, for example, flavored soups and wines, while cumin and coriander seeds made condiments and medicines. The pistils of the saffron crocus seasoned and colored foods and were also used in perfumes and as an important yellow dye. The most common “bitter herbs” were watercress, chicory, dandelion, lettuce, endive, and sorrel. Marjoram was probably the Biblical “hyssop,” which served for purification and in cleansing lepers. Perfumery was of particular importance in Biblical times, both for daily use and for ritual functions, and in many cases the same plants were employed in perfumes and medicines. For instance, the rare and costly gum of the Balm of Gilead, a small evergreen tree, was an ingredient of both Wormwood, a name given to several woody plants with a strong aromatic odor, was also used in medicine and perfumery. The “aloes” of the Old Testament were not true aloes; they are thought to have been eaglewood.

Naturally, the Hebrews included local plants and plant products in the incenses and anointing oils used for religious ceremonies. During the Feast of Tabernacles, myrtle and willow branches were braided with palm fronds to form the sacred Lulav, which was held in the right hand during the ritual, while at the same time a citron (the goodly tree), called “Ethrog” ceremonially, was held in the left.

The “cassia” of the Bible refers to two different plants. In Exodus, Proverbs, and Songs, it refers to cassia bark (cinnamon), a common spice and perfume. The ripe fruits of the tree yield oil of cinnamon, one of the ingredients of the holy oil with which officiating priests in the tabernacle were anointed. Another “cassia” is the Indian orris, a thistle-like plant widely used as a Temple perfume and incense.

Of all the ceremonial plants, perhaps frankincense and myrrh are the most familiar. The first often came from the tree Boswellia carterii, and its bitter, much-sought-after gum was used in the sacrificial services of the tabernacle and Temple. Myrrh is a gum from Cistus villosus, a thorny shrub or small tree native to East Africa, whose wood and bark are strongly scented. It was used in embalming, in perfumery, was burned as incense, and — together with aloes, cassia, cinnamon, and olive — was...
A Garden of Herbs
an almost indispensable ingredient of holy oil.

Another oil-yielding plant was the “gourd,” mentioned in Jonah 4:6, which has been identified as palma Christi, the common castor-oil plant. The oil, obtained from the large seeds, was used extensively in ceremonies, as was the highly perfumed gum of the “stacte,” mentioned in Exodus. Stacte is the sweet storax, a small tree with beautiful, aromatic flowers.

The bay tree, or laurel — an evergreen sometimes called sweet bay — also figured in religious ceremony. Its aromatic leaves flavored foods, its roots and bark supplied medicine. It was a mark of triumph, adorning the brows of priests, poets, and victors, while David used the laurel as a symbol of prosperity.

References to flowers abound in the Scriptures. Unfortunately, many are not mentioned by name, and some of the names given are so vague that translators and botanists do not agree on their identities. Today most botanists agree that the Hebrew Shushan, once translated as “lily,” or “lilies of the field,” refers to the anemone or windflower. The “lily of the valley,” on the other hand, is believed to be the hyacinth, whose blue blossoms brighten both fields and rocky places. Another “lily” is the iris, or yellow flag, that grows in shallow waters on the margins of ponds and streams, sometimes in extensive masses.

The “rose” of the Bible is thought to be the narcissus in some passages, and the oleander in others, but the “rose of Sharon” refers to the tulip. “Dove’s dung” is the star-of-Bethlehem — a spring-flowering plant whose bulbs served as food during times of drought and starvation. “Tirzah,” in Song of Solomon 6:4, is acknowledged to be the crocus.

The grapevine is the first cultivated plant mentioned in the Bible: indeed, there are more references to vine-growing and wine than to any other plant or plant product. Grapes supplied fresh fruit, raisins, a sweet syrup known as “dibs,” and vinegar, as well as the alcoholic beverage. There are many laws in the
Old Testament relating to the selection, planting, care, harvesting, pressing, storing, and tithing of vines, grapes, and wine.

Trees, many of which were venerated as sacred, played important roles in the lives of people of the Holy Land. There is a great deal of controversy over the hundreds of tree references in the Bible, and the identities of the evergreens—especially fir, pine, cypress, juniper, and cedar—are in doubt.

The cedar of Lebanon is one of the most sacred of Bible trees. Chief among the evergreens, it was known as the “Prince of Trees” — a symbol of grandeur, might, majesty, and dignity. Many Lebanon cedars are over 2,000 years old. Their wood is so rot-resistant that they were cut in great quantities to construct Solomon’s “House of Cedar” and the Temple. The great cypress forests of Biblical days were called “gopher-wood” groves. Because of its durability, cypress was used to build idols and ships—it may have furnished Noah with wood from which he constructed his ark.

The very word Palestine means “land of palms.” All manner of foods, beverages, confections, ornaments, fuel, household utensils, clothing, footwear, and cordage were supplied by the flowers, fruit, seeds, fronds, and trunk of the palm. For the Hebrews, the palm was a token of triumph, carried in processions. Indeed, the Israelites’ palm festival preceded today’s Christian Palm Sunday.

As important as the palm, economically and religiously, was the olive tree—a symbol of peace. Its gnarled trunk and spreading, silver-green foliage remain characteristic features of the Mediterranean landscape. Moses called the Land of Canaan a “land of olive oil.” In addition to food, the olive supplied illuminating oil, and was used in soaps, cosmetics, and medicine. It was a constituent of the holy oil used for anointing royalty and for Temple ceremonies, and its beautiful, hard wood decorated the doors of the Temple.

The almond is the first tree to flower in the Holy Land, and is in full bloom in January. Shaked, the Hebrew word for almond, means “hasty awakening.” This is dramatized in the story of Aaron’s rod, which in a single day burst into bloom and yielded almonds as a sign of the fulfillment of God’s promise. Oil, ointments, and cosmetics were made from the nut, as was a favorite food flavoring.

Of all tree fruits, the acorn may have been the first gathered by man. Forests of various species of oaks once covered the hills and mountains of the Holy Land, and many of the events of Hebrew legend and history occurred beneath oak trees. Oak worship was firmly established among the pre-Israelites of Canaan. The oak is still considered the “King of the Forest,” an emblem of majesty and strength.

The tamarisk and acacia also figure prominently in the Bible. The tamarisk, a small tree, grows in barren, sandy areas where its shade is greatly appreciated. In spring it bears spikes of beautiful blossoms that envelop the whole tree. The acacias, with their aromatic, long-lasting wood, are among the most beautiful, fragrant, and useful of plants. Exodus 27:1 says, “Thou shalt make an altar of shittim wood . . . ,” and the reference is to acacia, credited in the Bible as material for the Ark of the Covenant and the Altar of the Tabernacle. Gum arabic, derived from these trees, was an important article of commerce, used in many industries. The yellow flowers were employed in perfumery; the pods yielded feed and food; from the chips of the heartwood came the drug catechu, and the bark was used to tan leather.

One of the four “Sacred Species” of the Feast of Tabernacles is the myrtle—an aromatic evergreen shrub or tree—that adorned huts or booths during this festival. Its dark, glossy, sweet-smelling leaves, its white or pink, perfumed flowers, and its bluish-black, aromatic berries were dried for condiments and perfumes. In the Bible, myrtle is regarded as a symbol of divine generosity, peace, and justice.

The “sycamore,” mentioned several times in the Bible, is really the sycamore fig, a tall evergreen with aromatic leaves and fruit that is small, spotted, and not particularly tasty.

The common fig, one of the most important of all Bible plants, is the first tree mentioned by name: “. . . and they sewed fig leaves together and made themselves aprons” (Genesis 3:7). The fig tree grows everywhere in the Middle East—among rock crevices, in old walls, and along terraces. Besides fruit for food, the small, spreading tree provided welcome shade and was a symbol of tranquility. Indeed, there is scarcely a better way in which to end this inventory of Biblical plants than to cite I Kings 4:25: “. . . and Judah and Israel dwelt safely, every man under his vine and under his fig tree.
Trees of the Lord
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Equatorial mounting of the 4" UNITRON refractor, Model 152.
The telescope, Galileo, and the origins of optical astronomy

By Simone Daro Gossner

In astronomical matters, the seventeenth century had begun most auspiciously with Kepler’s discovery of the laws of planetary motions. Almost simultaneously, the invention of a new instrument was destined to furnish immediate proof of the validity of heliocentric theories. The origin of the telescope is shrouded in mystery. If two mple lenses are aligned in a certain manner in the line of sight, they enable one to view distant objects more clearly. It is possible, as one account tells it, that this property was discovered accidentally (ca. 1605) in the shop of a Dutch spectacle-maker. Yet, crude combinations of lenses and prisms seem to have been designed—in theory if not materially—in the latter part of the sixteenth century. In any case, the great Galileo (1564-1642) was among the first astronomers to grasp the potential of the instrument for serving the heavens, and to adapt it for this purpose.

Only two months elapsed from the day Galileo contrived a telescope that satisfied him—his fourth—to the publication of his pamphlet Sidereus Nuncius (Sidereal messenger) on March 10, 1610; but in those two months he learned more about the universe than had ever been surmised since the dawn of mankind. The priority of some of his discoveries was a matter of dispute almost from the start because the astronomical use of telescopes had spread rapidly. Historians of science are still arguing the point. It is testimony to his genius, however, that Galileo did not sit himself to a mere recording of observations, but that he was able to sense their implications at once and to analyze them with faultless logic.

The first telescopic discoveries had a shattering impact on prevailing cosmological concepts: gone was the orderly world in which planets were wandering pinpoints of light against a background of a few thousand stars, and in which the sun was a perfect orb of pure fire. All of a sudden, the moon stood revealed as a rugged body with a continuous surface, its peaks casting long shadows, countless stars and nebulous objects appeared where only empty space had been seen before. Planets acquired visible disks. Venus and Mercury showed phases like the moon’s; Jupiter turned out to have not one but four moons (although no one would believe this at first); Saturn sported quite definable but certainly peculiar appendages; and Mars—their spots crossing the sun were actually blanched on what should be a perfect surface.

The phases of Venus and Mercury were immediately recognized by Galileo as proof that those planets revolve around the sun. The Ptolemaic system assumed that they revolved always between the sun and the earth. If this were so, a telescope would show them at all times in a crescent phase; on the contrary, they were found to exhibit alternating crescent and gibbous phases, a phenomenon that could be explained only by assuming that their distance from earth is alternately smaller and greater than the earth’s (see illustration on p. 43, upper right).

The telescopic discovery of Jupiter’s four principal sat-

Huygens’s 1643 moon drawing is still crude, but main features, such as the ray structure of craters, are visible.

Galileo drew the moon he saw through his telescope for his book Sidereus Nuncius, first published in Venice in 1610.
ellites removed a serious obstacle to the acceptance of Copernican theories. Until then, even those scientists who were favorably disposed toward the heliocentric view considered it illogical that the moon alone should revolve around the earth whereas all other planetary bodies moved around the sun. Jupiter's satellites served to prove that this occurrence is not unique in the solar system. At first, however, news of their discovery was received with utmost incredulity in all quarters. Disciples of Aristotle, who were still numerous at that time, refused to believe in their existence on the grounds that Aristotle had never mentioned them. Kepler himself, when he first heard of it, found it hard to accept the fact that Jupiter should have four moons when the earth—this eminent abode of life—has only one; a few months later, however, he was able to observe them through his own newly acquired telescope.

Features of the lunar surface were among the most readily accessible to a primitive telescope. Accustomed as we are to photographic observations, we may be startled by the crudeness of Galileo's early drawings (see page 41, top), but it is a fact worth noting that he was able to derive the approximate height of lunar mountains from the pattern of light and shadow on the moon's surface.

The rings of Saturn were almost at the limit of the power of Galileo's instrument. His contemporary, Christoph Scheiner, S.J., saw them in the form of two lobes projecting on either side of the planet, but Galileo attributed this effect to inferior optics in Scheiner's telescope and maintained that they were two motionless companions of Saturn. Half a century elapsed before their true shape could be established without ambiguity (by Christian Huygens in 1659). The solution of the problem had been retarded further by an extraneous circumstance. The rings are extremely thin and the tilt of their plane to our line of sight varies from year to year. When they are seen edge-on, they almost vanish from view and even powerful telescopes could not reveal their shape. Although Huygens possessed a suitable instrument as early as 1655, the position of the rings at that time was most unfavorable, and only in subsequent observations did he gradually discover that they were circular in nature.

Under favorable conditions, sunspots may be seen with the naked eye. They had been observed on many occasions in pretelescopic times, but invariably they had been attributed to external causes: planets in transit across the sun's disk, distant birds in flight. Sustained telescopic observations revealed that the spots are of varying size, that some are short-lived whereas others persist for over a month and that all share a common motion across the solar surface. After much soul-searching, Galileo decided that these were the features of the sun. He concluded that the latter is rotating on an axis and that its spots share that rotation. It is not surprising that Galileo should have been so reluctant to propose this interpretation. The idea of a blotted sun ran afoul of all philosophical concepts concerning its nature; but, as telescopes improved and observations accumulated, his conclusions became indisputable.

On the average, stars appear fainter when they are farther away; therefore, every time the power of a telescope is increased to reach fainter stars, a larger volume of space comes under scrutiny. Since the volume of a sphere increases as the cube of its radius, the number of fainter stars that become observable increases in essentially the same proportion. For the same reason, the number of stars that lie just beyond the limit of the unaided eye is qu

Jupiter and the schematized orbits of its four principal satellites, as first discovered by Galileo, were published by M. Hirzgarter in Detectio Dioptica.

Saturn's rings, as viewed through a 17th century telescope, were not corre
As soon as Galileo directed his modest telescope toward the Milky Way, he discovered thousands of new stars. The implications of this fact were not grasped immediately; this may be the reason why his description of rich star fields in Orion and the Pleiades evinced few reactions from his contemporaries. A few decades later, however, one of his followers expressed—rather timidly—the opinion that stars of greatly different brightness must lie also at greatly different distances. Thus the first hole was punctured in Ptolemy’s "eighth sphere," the sphere of fixed stars that was believed to form the boundary of the solar system, and the existence of which no one had ever had reason to question until then.

The most remarkable feature of these early telescopic discoveries is that they could be accomplished with such imperfect instruments. Glass was of poor quality; lens-grinding techniques were primitive; and the distorted images produced by simple lens systems were sometimes unrecognizable. The observer had to draw, mostly from memory, what he saw through the eyepiece, and the journey from the astronomer's sketchbook to the printer's engraving certainly did not add to the accuracy of published results. As a case in point, we show on this page (below, right) what may well be the most startling picture of the planet Mars in all astronomical literature. It appears in a pamphlet entitled Detectio Dioptrica, published in 1643 by the Zurich mathematician Matthias Hirzgarter. In defense of the Copernican system, the author presents the latest observations of an unnamed "Neapolitan gentleman" who had sent them to him "through a trusted friend in Padua." The anonymous Neapolitan was probably Francisco Fontana, who claimed to have modified the Galilean telescope.
THE SKY IN JUNE AND JULY

From the Almanac:

<table>
<thead>
<tr>
<th>Event</th>
<th>Date</th>
<th>Time</th>
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<tr>
<td>Last Quarter</td>
<td>June 5</td>
<td>4:19 P.M., EST</td>
</tr>
<tr>
<td>New Moon</td>
<td>June 13</td>
<td>12:17 A.M., EST</td>
</tr>
<tr>
<td>First Quarter</td>
<td>June 21</td>
<td>4:02 A.M., EST</td>
</tr>
<tr>
<td>Full Moon</td>
<td>June 28</td>
<td>7:35 A.M., EST</td>
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<tr>
<td>Last Quarter</td>
<td>July 4</td>
<td>10:33 P.M., EST</td>
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<tr>
<td>New Moon</td>
<td>July 12</td>
<td>2:12 P.M., EST</td>
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<td>First Quarter</td>
<td>July 20</td>
<td>6:14 P.M., EST</td>
</tr>
<tr>
<td>Full Moon</td>
<td>July 27</td>
<td>2:51 P.M., EST</td>
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The summer solstice will occur on June 21 at 10:30 A.M., EST. On that date, the sun will reach the northernmost point of its annual course and summer will begin in the Northern Hemisphere. On July 5, the earth will be at aphelion, the point of its orbit farthest from the sun.

For the visual observer:

Mercury, at its greatest eastern elongation on May 31, will be visible near the western horizon, shortly after sunset, during the early part of June. It will set about one and three quarter hours after the sun on June 1, one hour after the sun on June 15. For the remainder of June and early July, the planet will be too close to the sun for observation because of its inferior conjunction with that body on June 27. It will rise an hour and a half before the sun in mid-July, one hour before the sun on July 31. It may be seen, very low in the east before sunrise, for several days previous to and following July 19, the date on which it reaches its greatest western elongation.

Venus will rise in the northeast at 2:30 A.M., local standard time, on June 1, 2:15 A.M. on June 15, 2:00 A.M. on July 1, 1:45 A.M. on July 15 and 31. A conspicuous object in the eastern sky at sunrise, its brightness will fade slightly from —4.1 magnitude on June 1 to —3.6 on July 31. It will pass south of the Pleiades in the early part of July.

Mars, in the evening sky (+1.3 magnitude), will set at 11:30 P.M. on June 1, 11:00 P.M. on June 15, 10:30 P.M. on July 1, 9:45 P.M. on July 15 and 9:00 P.M. on July 31. Although it is in Leo for most of this period, it will pass near Regulus at the end of June.

Jupiter, in Capricornus (+2.2 magnitude), will rise in the southeast at 11:00 P.M. on June 1, 10:00 P.M. on June 15, 9:00 P.M. on July 1, 9:00 P.M. on July 15, before sunset on July 31. It will remain visible for the rest of the night throughout that period, except toward the end of July, at which time it will set in the southwest approximately 30 minutes before sunrise. It will be at opposition (on the meridian at midnight) on July 25.

Saturn, in Sagittarius (+0.4 magnitude), will rise about half an hour before Jupiter during both months and will be at opposition on July 19. It will remain visible for the rest of the night in June and early July but will set about an hour before sunrise by July 31.

Meteor Showers:

The Delta Aquarids may be expected on July 29. Normal maximum for this shower is twenty meteors per hour as seen by a single observer. However, the moon will be two days past full on that date and will interfere with observations. A few Perseids—presaging August showers—may begin to appear in the early morning at the end of July.

On the preceding pages, Mrs. Gossner offers the sixth in her 1961 series on the growth of cosmological concepts.
A Question in Whale
Most solitary strandings seem to be in response to sickness

By Carleton Ray
WHALES—some of them gigantic almost beyond comprehension—bring to mind the awesome, powerful, and mysterious. Today, we even suspect that they are as intelligent as any mammal but the primates. These “reconstructed” land animals, reversions to a life in the sea, occasionally return again to land. The reasons whales do this—stranding themselves, usually to die—are the subject of investigation of this article. At the New York Aquarium, we have had first-hand experience with strandings of two species of the smaller whales, and two species of their relatives, the porpoises and dolphins.

The feelings of most people who encounter a large whale stranded on a beach have been summed up by the Dutch artist who in 1598 made the delightful copper engraving shown on pp. 46-47. This is a male sperm whale (Moby Dick was one), the source of spermaceti, sperm oil, and ambergris. A champion diver, it goes down a half-mile or more in search of the formidable giant squid—its favorite food.

Who can help but be excited when he finds one of these giants on a beach! Sometimes the animals are stranded alive. As the whale struggles in the ebb tide, it only manages to dig itself deeper into the sand. Its expressionless mouth may occasionally gape, or a rush of air may issue through the blowhole on top of the head. As the ebbing water deserts the body, the creature’s weight becomes its own worst enemy, bearing down upon the chest, eventually causing suffocation.

The words “whale,” “dolphin,” and “porpoise” need not confuse one as applied to those mammals which, together, make up the order Cetacea. Scientifically, the cetaceans are divided into two suborders; one is composed of toothed animals and the other of those that have baleen or whalebone—an epidermal derivative that is homologous to hair or nails instead of teeth.

SPECIES of the latter suborder: the Mysticeti, feed on plankton strained from the sea through the whalebone that hangs from the upper jaws. All the mysticetes are large, so all qualify as whales. The range in size from the pygmy right whale, *Neobalaena marginata* (length to 20 feet), to the largest animal that ever lived, the blue whale, *Balaenoptera musculus*, that reaches lengths...
ver 100 feet and weights of more than 20 tons. There are few kinds of mysticetes— a few species of orcas (including the blue, finback, and sei whales), gray whales, humpbacks, right whales and bowheads.

The toothed cetaceans—suborder odontoceti—include some whales, but membership is primarily composed of porpoises and dolphins. The odontocetes are a large group, comprising several families of several dozen species. Which of them is called whale, and which dolphin or porpoise, is generally clear if one but mildly considers its zoological relationships. The really huge, toothed cetacean is the aforementioned sperm whale, Physeter catodon, males of which occasionally grow to more than 60 feet in length. The female is about half the size of the male. The odd and rare beaked whales of the genera Mesoplodon, Ziphius, Hyperoodon, and Berardius grow to moderate size, mostly an, 15 to 30 feet. Berardius is the largest, reaching over 40 feet.

Fortunately, the smallest cetaceans at common call whales all fall to small, special families: the white whale or beluga, Delphinapterus leucas, and the strangely armed narwhal, Monodon monoceros, together constitute the family Monodontidae. The grey sperm whale, Kogia breviceps, a diminutive member, and the only other living member, of the family to which Moby Dick belonged, the Physeteridae. All three of these little males mature at close to ten feet in length, but their zoological peculiarity lies even the layman to distinguish them as "whales" from the dolphins and porpoises.

The family Delphinidae, largest of the cetacean families, includes some species large enough usually to be called whales. The male killer whale, Orca, grows to thirty feet, while the largest male pilot whale, Globicephala, nearly that large. We call small members of this family dolphins, but members have in common their be-shaped teeth. The best-known are the common dolphin, Delphinus delphis, and the bottle-nosed dolphin, Tursiops truncatus.

The porpoise family, Phocoenidae, turn, all have spade-shaped teeth and are small. Best-known is the harbor porpoise, Phocoena phocoena (large male is scarcely six feet long). Handsome and smaller porpoise is the Dall's porpoise, Phocoena dalli.

This is one of the smallest of cetaceans, reaching a mere five feet. Here we are concerned with four species by these definitions: two species of whale, a porpoise, and a dolphin that were stranded or trapped in shallow waters. All but the porpoise, which died en route, were brought alive to the New York Aquarium for observation.

How do whales and their relatives live their highly specialized lives? Marine mammalogists are just beginning to learn some answers to this question. Quite a bit is known of cetacean anatomy, less of behavior, and of the way in which they use sound in their delicate underwater navigation. We have scattered information on birth, migration, and death. But as yet we are in possession of only fragments of the total life picture.

One way of learning more is to take advantage of the fact that some whales are stranded alive. Such delicate measurements as electrocardiograms have been taken under these circumstances. Dead, stranded animals may be measured, and some of their organs preserved. Every so often it is possible to bring a stranded animal back to captivity, where it can be ob-

on land, body weight pressing on the lungs can cause a whale to suffocate. We served over a period of time. What we discover in such cases may be only a slight beginning of knowledge, and as we shall see, most of it is knowledge about sick animals. Nevertheless, sickness is a part of life, too, and this information may prove to be more important than we now can determine. Finally, small whales and their smaller relatives are presently being kept successfully in captivity. A third generation bottle-nosed dolphin is now thriving in Marine Studios, Florida, never having seen the sea at all!

No one can guess how many cetaceans are stranded annually through-

Ten-foot beluga from Prince Edward Island, trucked to Aquarium in a large wooden tub, was partially covered with water and cushioned with burlap bags.
out the world, although scientists, particularly in England, have for years kept records of reported strandings. In the last three years, we have observed five pilot whale strandings on Long Island and New Jersey shores alone, and surely this is far from a total count for this species for even one short length of the Atlantic coast.

Why are cetaceans thus stranded? This is a question to which we are beginning to get an inkling of an answer. First, strandings of a single animal are one thing; they occur quite frequently. Mass strandings, involving whole groups or schools of cetaceans, are quite another matter.

Several expressions are used to describe one theory as to why schools of some whales, particularly the pilot whales, come ashore. “Mass mania” is one; “group hysteria” or “death wish,” others. But these bits of psychological—and anthropomorphic—phraseology really say little or nothing. The fact is that groups of apparently healthy animals will drive themselves onto the beach, where they suffocate or die in the sun. A further fact is that, if forcibly hauled out to deeper water, the animals will swim back up on the strand. One dubious theory sometimes offered to explain these mass strandings is that the school follows a “pilot.” If something happens to this animal, the whole school goes awry. But not nearly enough is known of pilot whale behavior to verify this theory. All that we can say is that these are highly social and group-dependent animals, and the reason underlying mass strandings may be related to that fact. As is well known by the Newfoundland whale drivers who herd their quarry to the beaches for the slaughter, schools of pilot whales can be driven to strand themselves in seeming panic. As we have noted, many strandings involve apparently healthy animals. If stress is a factor, perhaps examination of the endocrine glands—particularly the adrenals—will yield a clue as to cause.

As to isolated strandings, the question is: why should an intelligent animal, equipped with an effective navigational system, be trapped in shallow water? Probably the correct answer in the majority of cases is that the animal is not in good health. Whale and porpoise may be as subject to sickness as other mammals. Autopsies of our stranded individuals indicate that some cetaceans are subject to such diseases of the respiratory tract as pneumonia. They also reveal that several roundworms parasitize both heart and lungs of some individuals, in addition to the many roundworms and flatworms common in the liver and digestive tract.

Thus it may be that a respiratory disease or parasitic infestation “gets ahead” of an individual animal which, as it becomes moribund, tends to fall behind the rest of the school. If far from land, it might die and sink to the depths of the sea or be attacked and eaten by predators—sharks or killer whales. Possibly, sick individuals that reach the protection of shallow waters may actually seek the support of land for their tired bodies.

Let us take as examples three East Coast Atlantic strandings of 1960. On May 13, a pilot whale, 12 feet 9 inches long, was stranded on Brighton Beach scarcely half a mile from the New York Aquarium. With the aid of the New York City Park Department, a wooden sled, and a tractor, we retrieved the animal and it lived in our tanks for 29 days. On July 4, 1960, a 10-foot beluga was captured from very shallow waters at Prince Edward Island, Canada. It had strayed in the Kildare River, far from its normal summer range in the St. Lawrence River, and had lived alone there for over a month until it was captured by local fisheries officers. It lived in captivity for 64 days. Finally, a 7-foot-inch common dolphin, Delphinus delphis, was stranded on the eastern shore of Staten Island on December 17. It was looked after by police until it arrived, and lived with us for over four days. These three are not the only cases we have met locally, but are only cetaceans brought back alive.

We suspected at the outset that all these animals were sick when they were stranded or captured where waters strange to them. We knew they would probably die in a short time.
tarts in center of the jaw and then moves to the front and to the back.

But we made every effort to effect a cure, even though we were in the dark as to the nature of the diseases. The longest that any stranded cetacean has ever lived in captivity is seven months.

Even though we had little hope of curing the animals, there was much we would learn by keeping them alive for even a short time. In the three cases died, we were able to take live weights when the animals reached our doors for whole weights at death—information that is rare indeed. We were also able to make photographs of the whole animals, and of various surface features—squid tentacle marks on the pilot whale, and circular marks on the beluga that looked surprisingly like the work of lampreys.

There was a major problem in transporting these three animals to the aquarium alive. Cetaceans are not adapted for life out of water, but they can be transported that way. Usually, they are carried on slings of thick rubber mattresses or on air mattresses. They are placed on their sides to relieve weight from the chest, and the body is covered with a light sheeting that is kept constantly wet to keep the animal moist and cool. Pictured on p. 63 is the beluga, which was trucked in a large wooden tub and partly covered with water. Under the animal, as cushioning and support, and to give stability, were many burlap bags. The water, 100, helped relieve the weight on the animal for, as stated earlier, when out of water weight is the whale's
Squid are wrapped around a stick and force fed to beluga that would not eat. Although it took three men to perform task, whale did not object strenuously.

worst enemy. It is not too serious a problem with small cetaceans, but can be critical for larger ones.

We dosed our captive animals with penicillin and streptomycin, and even with vitamin shots and tranquilizers. Although the results were hard to assess directly, we have accumulated some knowledge of the dosages required for handling and treating these three species. On the whole, we suspect that except for certain tranquilizers to which these animals may be sensitive, the dosages are not atypical of other mammals. Under the direction of Dr. Ross Nigrelli, pathologist of the New York Aquarium, and with the cooperation of several physicians, eyes scraped or partially punctured by beach sand were cured, sunburn alleviated, cuts and abrasions healed.

Feeding was the greatest problem. Before using any forceful methods, we continually tossed dead fish and squid to the animals, and even placed specially collected living fish and squid into their tank. On its second day in captivity, the common dolphin surprised us by feeding heavily, and continued to do so until the day before its death. The pilot whale and the beluga steadfastly refused the food handed to them by a swimmer in their pool or tossed to them. In consequence, we developed a technique of gentle force feeding. Twice each day we drained the pool of all but a foot of water. Three men then went in with the whale. One took up his position at the animal's tail and two stood at its head. The mouth was gently pulled open by one of the two "head" men. The whale did not particularly resist this manipulation. The other head man thrust a morsel down the whale's throat to the back of the tongue. The whale was then allowed to close its mouth, and the fish was swallowed voluntarily. Only toward the last days of life did any regurgitation occur. We learned that a bit more than 25 pounds of squid could be given to our pilot whale at a "sitting," and almost 20 pounds to the beluga. It is doubtful if either of these sick animals would have lived so long without this feeding technique.

We could observe only a few things about the behavior of a sick, none-too-active cetacean in captivity. We did manage to evolve a rough sort of "index of stress," based on the animals' breathing rates. When first brought to our tanks, the intervals between breaths were short, as was the duration of the breath; respiration was not unlike gasping. We have the best records for the pilot whale and the beluga. Both began with breathing intervals of approximately 1/4 to 1/2 minute. This interval lengthened over a period of a few days until a pattern was set up, characteristic for each individual. This consisted of one or more short intervals—from nearly one minute to two minutes—with several short five- to thirty-second intervals between. These shorter intervals in succession resembled the human diver technique of hyperventilation as means of "storing up" oxygen. At this point when this more regular breathing pattern is adopted, the animal may be assumed to be accustomed, comparatively, to its confined surroundings.

We also noted that the pilot whale is less maneuverable than the extremely supple beluga, which is able to scull with its tail to swim backward.

Another remarkable thing we noted during the short lives of these sick animals was their extreme gentleness. Only the beluga attempted to bite, at it was not a hard bite at best. Occasionally, our patients snapped their jaws threateningly—but for the most part the animals were docile and easily handled. The pilot whale seemed to recognize one keeper who often swam with it, or at least it recognized the keeper with good intentions. We discovered that this animal enjoyed having its sunburnt skin scratched with a piece of rough netting, so daily it was accommodated with this treatment.

Eventually, all three animals died. Autopsy by Dr. Nigrelli revealed a remarkable coincidence—all had suffered from advanced cases of pneumonia, the lungs being abscessed and full of pus. Roundworms were associated with the infection in the pilot whale and the beluga. This coincidence is fortified by another case. A local stranded harbor porpoise, which did not reach our tanks alive, showed the same condition of advanced lung infection and parasites. Whether parasites have anything to do with animals' susceptibility to pneumonia is not known. What we can say, on the basis of our experience, and that of others, is that cetaceans stranded all will probably have respiratory infections. If such diseases involve difficulty in breathing, which seems likely, they may well incline the animals to sink, shallow waters and even a fatal pillow that the beach affords.

Mouth of the beluga is held open wide while squid are pushed to back of the tongue.
Near-total eclipse, due on August 25, will almost equal spectacle seen ab
CELESTIAL EVENTS

A list of astronomical occurrences for the second half of 1961

By K. L. FRANKLIN

JULY

JULY 5: The earth is farthest from the sun on this date—
6 million miles.

JULY 19: For the next twenty nights the fleeting streaks
light seen occasionally in the sky may be associated with
a meteor shower named for the star, Delta Aquarii. The
maximum count one observer could expect is about twenty
meteors each hour about July 29. Unfortunately, the moon
will be just past full at that time, and will seriously inter-
fer with observations.

JULY 26: The moon will be closely followed across the
y tonight by Saturn and Jupiter.

JULY 27: The moon will pursue Saturn and Jupiter to-
ight, following Jupiter by 5° about 11:00 p.m., EDT.
Watch for this celestial leapfrog until November.

AUGUST

AUGUST 10: For the next five nights the Perseid meteors
near their annual appearance. After midnight, one ob-
server may count nearly one meteor per minute. A true
member of the shower will appear to streak away from a
point in the constellation of Perseus, low in the northeast.
Sporadic meteors will not show this characteristic.

AUGUST 11: An annual eclipse of the sun will be seen
in the middle of the Atlantic Ocean. No significant
sunspot path will cross land, but parts of South America
and South Africa will experience a partial eclipse. The
eclipse is annular (ring-shaped) rather than total, because
the moon is 252,500 miles away at this time, nearly as far
from the earth as it can get, hence appearing about 7 per-
cent smaller than the sun.

AUGUST 23: People near the ocean may wish to know
that unusually high and low tides will occur this afternoon
at nearly the moon will be full.

OCTOBER

OCTOBER 11: Early risers who wish to see Uranus may
find it less than one-third of a degree north of Regulus
this morning. This star, the brightest in Leo, is about the first
magnitude on the astronomic magnitude scale, but the
planet is about the sixth magnitude, as faint as the average
person can see without optical aid.

OCTOBER 29: This morning, 2:01 a.m., EDT, becomes
1:01 a.m., EST. Daylight Saving Time ends in many parts
of the United States. Set your clocks back one hour.

NOVEMBER

NOVEMBER 13: A short time after sunset this evening,
Saturn, Jupiter, and the crescent moon form their monthly
triad in the western sky.

NOVEMBER 23: This evening, the moon will again occult
Aldebaran, the bright, orange star in Taurus. Although the
star is bright, the moon is only a half-half past full. Binocu-
lars will help in observing this event.

NOVEMBER 29: This morning the moon occults the
bright star Regulus. It will be dark on the Pacific coast, but
eastern observers should use a telescope to time the event.

DECEMBER

DECEMBER 10: Clear, crisp nights and a moon setting
fairly early will help in the observation of the Geminid
meteors this week. One observer may see about fifty an-
hour by the thirteenth of December and, occasionally, a
brilliant fireball associated with this shower.

DECEMBER 21: At 9:20 p.m., EST, the sun has reached
its most southerly point in the sky, the winter solstice.
Although summer begins in the Southern Hemisphere, the
days up north will begin to lengthen, promising spring in
spite of the months of winter weather that still lie ahead.

Dr. Franklin of The American Museum—Hayden
Planetaryarium prepares this summary each six months.

55
Myriads of Moths

By George Ordish

Under natural conditions, the animals belonging to the dry-litter habitat are rare, because of the scarcity of dry litter in nature. Wet litter is very common, particularly in the woods, at the foot of cliffs, and so forth, where rotting vegetation, dung, and animal remains may be found, together with a special fauna—such as earthworms, wood lice, springtails, mites, and millepedes—all living in and on these wet-litter substances. By contrast, dry-litter habitats under natural conditions are found only in the nests of certain birds—those placed on cliffs or in dry caves, for example—or in a few dry deposits of dung from bats or birds. These are very rare positions compared to wet-litter sites, but they contain their own special fauna.

The dry litter tends to consist of high-protein material such as waste hair, feathers and fur, or dung, which has a high nitrogen content. The creatures living in dry litter, or some of them, were first of all predators on other small animals and then became scavengers of such discarded materials of higher animals as molted feathers and hair, cast snakeskins, and dung. They lived specialized lives within their unusual realm and had to perfect devices that would economize water, the scarcest material in their chosen environment.

When man came on the scene, he had a considerable effect on these animals, because he was a great consumer of dry litter himself: he filled dry places—caves, huts, castles, houses—which he would keep warm and, to begin with, not particularly clean, so that a vast new dry-litter habitat was created. Even though he was not covered with fur, did not molt or cast his skin, and did not leave his dung in his own abode, yet he started to wear clothes and scattered bones with meat on them about the floors of his caves, huts, and castles. His first clothes (skins and fur) were to those dry-litter animals a huge supply of their chosen medium, and man began to weave coverings of it.
to keep them in chests and cupboards, the animals began to move of the birds' nests and bat dung and take to clothing as their main source of attaining a livelihood.

Man moved forward to improve his world, so he influenced the of many other creatures; he increased the opportunities and numbers of these erstwhile scaveners, a step that caused considerable favor to their hosts. They did however, abandon their old sphere of life and seek out, in birds' nests and deposits of dry droppings, and frequently it is from these sources that creatures spread into man's stores of food and accumulations of clothing.

Man's homes, of course, provide the chief shelter, and one such - now known as Bartons End - was erected in 1355 in the county of Kent in southeastern England, when a certain Squire Barton built a farmhouse for his newly married son (illustration, above). Its first inhabitants, though, were not the newlyweds but wood-horers, already present in the very timber used in the building. As successive generations of animals and men passed through this house, various cycles of life forms entered an organic pattern to make what might be called "the living house." One such is that of the dry-litter community.

What we now call the clothes moth is the principal member of this community. There are, in Britain, some five different kinds of moths that will feed on man's dry litter. Three are clothes moths and two are house moths: the three are the common, the case-bearer, and the white-tip clothes moth; the two house moths are the white-shouldered house moth and the brown, or false, clothes moth. To
Techniques of moth prevention were not really grasped by 17th century inhabitants of Bartons End. When storing clothes in “mother’s moth-proof chest,” they believed was sufficient if the garments were free of all obvious

these must be added the spider beetle and the carpet beetle, which operate in much the same way as do the clothes moths. The furniture mite is another animal that belongs to this group, and there are many more that have specialized in sharing man’s stores of food. The flour beetle is among the commonest, but others, as the Indian meal moth, the grain and rice weevil, the fruit moth, and the bookworm, have been added as trade and commerce interchange both animals and goods from one part of the world to another.

These were the main dry-litter creatures that fed on man’s goods at Bartons End, but they were not the whole dry-litter community. There were a number of other creatures that benefited from these sheltered conditions. Silverfish gradually developed in the house, but did not do much damage; they are the most primitive of all insects and can be described as living fossils, though very minute ones. The Bryobia mite, or grass spider, frequently came to the house to pass the winter and was fond of the thatch, the lower and upper layers of which formed part of the dry-litter habitat, particularly by 1660, when six layers of new thatching straw had been laid on the roof without all of the old thatch being completely removed from under the new layers.

Here, mites, psocids, silverfish, springtails, fleas, Protura, and even woodlice abounded. But much of this old thatch was moist because it was in bad condition, being so thick that it never fully dried out. Consequently not all the thatch can be considered as the dry-litter world. Moreover, it was not a high-protein dry area, but a comparatively low-protein, high-carbohydrate zone. Many of the scavengers here were actually living on molds growing on the straw rather than on the straw itself. Strangely enough, the top layer of thatch was more often dry than wet, because the wind or the sun dried it so quickly after rain, but the variation made it an unattractive habitat.

Clothes moths were well known to the Elizabethans; their clothing was wool, linen, and leather – with a little silk provided for the most wealthy – and all these except the linen would be attacked by the clothes moth. Brushing, airing in the sun, putting the clothes away clean, and layering lavender and laurel in the closet chests were the methods Mary Baskett used to combat the ravages of the insects. They were effective, too; except perhaps the lavender, though it may have had some slight repellent action on the adult moths, and still is so to this day.

Through the centuries the house was improved so that it was kept warm and the clothes moths thrived increasingly. Now that the present owner has the place centrally heated, there is another crisis in the lives of the clothes moths because, though they like the heat, it is becoming too dry for them. Moreover, mothproofing clothes and clothing are an additional blow on an increase in their numbers. Some are artificial fibers like nylon or...
xylene; neither are modern manufactured woolens all that a clothes moth wants, for it will breed much more quickly on raw wool, which obviously contains some vital substance relative abundance, compared with manufactured article. It is only clothes moths that have completely adapted themselves to living on fabric; if the clothes are clean, moths cannot eat them but they prefer soiled material, containing sweat, food, or remnant, which enables them to obtain supplies of vital elements (possibly certain fats, vitamins, and amino acids) more readily than from clean fabric alone. This is one of the reasons why putting clothes away clean is to protect them from moths.AILY, moth powders and sprays on DDT are a serious threat to the moths' survival as a race. Together with their enemies, the spiders, are declining, though by no means extinct as yet. Still, they have overcome many setbacks in arriving at their present way of life and, breeding as fast as they do, they may yet overcome these new-found difficulties.

Here we can see the struggle for survival imposing this pattern of life on the clothes moth. A medium containing food material, protein, carbohydrate, vitamins, and water, albeit this last was comparatively scarce, offered itself and was duly colonized. To do so the creatures had to acquire some special habits, for they had to be able to digest the fibrous proteins found in wool, hair, and leather — such as keratin and fibroin — which are digested by few animals. Nevertheless they have done so; they had to, or else leave the field untouched. Measurements have shown that about half of the fabric consumed is actually used by these animals, and the rest is excreted after very slow digestion.

The creatures can readily obtain oxygen from the air. Their large surface area, compared to their weight, makes this easy as they breathe through pores in their skin (spiracles) not by means of lung books. The larvae live on or in the medium the whole time so the question of water supply is important. As they breathe they lose water; they obtain very little with their food, for wool and hair do not contain much of this substance so essential to life; to overcome this difficulty they have acquired the ability to absorb water directly from damp or dampish air. By this means their vital supply of water is maintained. They are able to vary the length of their larval life considerably, which fact also has a notable survival value. When food of the right kind is scarce or water cannot be obtained either from food or the air, the larvae can rest or develop more slowly and into a much smaller adult — perhaps a tenth the weight of the normal insect — though still, if a female, able to lay fertile and viable eggs.

The drying of the atmosphere of the whole house by the central heating system is a big threat to the way of life of the clothes moth for it makes the question of water supply acute. On the other hand, it also provides warm conditions all the winter, thus clothes. They did not realize that the stored clothes had moth eggs on them that hatched and thrived in the chest.
shortening the life cycle and enabling the generations to succeed each other more rapidly, which causes their numbers to build up again. The balance between increase and decrease is a narrow one: very small things may make all the difference to the success or failure of an animal. However, clothes moths are not very likely to become extinct so long as birds are encouraged. While sparrows can force their nests under the gutting or eaves, and martins build on the walls, there will always be a supply of various of these creatures ready to find their way into the house, with its vast supply of dry litter. As soon as a dry-litter animal finds itself in a favorable position in a house, its numbers will build up very quickly.

First of the clothes moths at Bartons End was the common clothes moth found in the sparrows' nests under the thatch of the eaves. The tiny eggs of this creature are oval and ivory-white in color; found singly or in groups of two or three, they are laid on top of tight-woven fabrics, or between the strands of wool in knits and looser woven cloths, the base of hairs in furs. Some eggs are deposited by each female but the quantity naturally depends on how well fed the moth was before laying. Shortly after laying they hatch; the eggs hatch with a week or ten days' time. The larvae are white with yellowish-tawny body, and are about three-eighths of an inch long when fully grown. As soon as they hatch, they begin to feed on "dry litter" on which the eggs have been laid. When faced with mixtures of animal and vegetable fibers, the moths seek out and consume on the animal ones. The material, if coarse, shows through the skin and makes the larva inconspicuous, a fact with a considerable survival value. Many maids and mistresses at Bartons End were not sharp-eyed enough to see the beginnings of an attack on their blankets, jerkins, hose, and the spoilage succession of garments throughout the history of the house, and so the tiny, vulnerable caterpillar portent to develop to maturity.
The common clothes moth larva usually builds a tube from silk and the fibers of the food medium on which it has been feeding at the time, protecting its head from either end to eat. When a new area is to be browsed, the larva either extends the tube or abandons it and constructs another one. Not all larvae do this; a few are free-feeding over the area, or just spin a little web silk to protect themselves, here again is posed a question as to the balance of advantages to the race. The tube protects the larva against certain parasites but renders it more conspicuous to man, while the free-feeding larva is less conspicuous to man but more exposed to attack from house and braconid parasites. Which is the greater danger?

The noise of a moth feeding, when amplified by microphone, is very startling — a vast tearing and rending of fibers repeated in a rhythm of three or four bites, followed by an interval of two or three seconds' silence, and then repeated. It is indeed fortunate for the moth that our unaided ear cannot pick up this sound, for such an alarming noise would not only advertise the presence of the moth but lead to instant defensive action as well!

Larvae of the common clothes moth by no means confine their feeding to wool and fur. At Bartons End, poisoned mice sometimes died behind the wainscots and these were attacked by a number of insects, including the clothes moth. The poison victims robbed a valuable source of moisture for the moths, for not only was the fur dead but the drying, but still moist, flesh on the mouse bones was also colonized. However, this attractive source of food also had its dangers for the moth, for those that attacked the mouse and viscera were killed by the same arsenical or phosphorus poison that had killed the mice. The moths attacking the dead mice helped devour the body more quickly and were advantageous to man in this respect, the action of the humans at Bartons End to reduce one animal obnoxious to them had the effect of increasing the opportunities for development of other equally objectionable.

The moths also occasionally made experiments in living on purely vegetable materials. In the early days of the house, they successfully managed to develop on a few porridge oats neglected in a sack, and on some

**Fluctuation in populations of three other non-human residents of Bartons End is shown on graph in relation to man's alterations over the centuries.**
crushed barley fallen into a corner in the brew cellar. However, in these cases, they always concentrated on the high-protein portion of the vegetable material. They also attacked garments of both silk and leather.

The ancestors of this moth seem to have lived as predators on the larvae of ticks, mites, and similar creatures and from this to have adopted the scavenging way of life as being easier; they then pushed on to attack man's goods. It appears a most adaptable animal and may well have genes in its makeup that will again face man with a new development. Nylon may perhaps fall into its power; it has already attacked the insulation of telephone cables in London.

After the larva comes the pupa: first a silken cocoon is spun, and attached to it are threads of the material on which it has been feeding. This economizes on the silk it has to spin, leaving more food reserves for the succeeding adult and the future generation, and is also an aid to concealment. The pupal case is formed within the cocoon: the duration of this stage is variable, lasting from two to six weeks, a lower temperature prolonging the process. At the end, the pupal case projects from the cocoon, splits at the end, and the moth emerges.

The newly hatched moths are a bright, golden-buff color. The wings free from markings and with rather loose scales, some of which easily become detached. The wing expanse is about half an inch, the males being a little smaller than the females. The female is full of eggs and rarely flies as she is so heavy; moths seen on the wing are nearly always males, or spent females who have already laid their eggs in some well-concealed spot and are then light enough to fly.

At Bartons End, the humans always chased and killed any small moth seen fluttering in the house. This did very little to keep down the population of clothes moths, because some victims were garden moths drawn to the lights at night or, if clothes moths, were the males or empty females who were about to die in any case. Of course, if enough males could be killed, the future population would be affected. But killing a few males will make very little difference to the numbers of the next generation, a fact which is true of most of the animal kingdom and is no doubt the reason why only men used to go to war and women did not. The moths, particularly the females, try to escape danger by running for shelter in quick, dodging, characteristic dashes, though sometimes they take short flights as an additional measure of evasion.

The length of life as an adult is again very variable; the males live longer than the females, the former averaging about four weeks and the latter half this time, or a little more. The adult moths tend to be abundant in early summer and in the autumn, but now at Bartons End they may be met with all the year round (owing to the central heating) although not in the large numbers that were known in the earlier days of the house.

It was generally concluded in the seventeenth century that insects and creepy-crawlies in general were spontaneously created out of "corruption"; that rotting meat engendered maggots; dung, flies; and shut-up clothes, moths. The mistress of Bartons End at this time accepted this to some extent, but noted first that the clothes were not rotting and, secondly, that the maggots in the clothes turned to moths. Hence she argued the moths could turn to maggots. There was even some confusion over the name, for the word "moth" had once meant the maggot, but now meant the flying creature, which to her suggested a close association between them. Ever practical, she decided to try keeping the moths away from the clothes by having a chest made with a very tight-fitting lid. Fortunately the clothes she put into it were free of eggs and larvae, so her theory was triumphantly vindicated.

But one of her daughters was not so successful with "mother's moth-proof chest," which she left full of clothes unopened for two years. Moth eggs had gone into the chest on the clothes when first put there and thrived in their closed community, for it happened that no parasites had gone in with them, nor could they get in, to restore the balance. Mother's moth-proof chest became a family joke.

William Harvey, the king's physician, published his book on the engendering of animals thirty-seven years before the unfortunate daughter's parent died, and his dictum — "Omne vivum ex ovo" — had appeared in one of the newsletters that the country family received from London from time to time. This had greatly intrigued the mother, though it did seem to flout the Old Testament, for did not the Book say "Out of the lion can forth sweetness"?

How often at Bartons End did the humans go to their stores to take a special garment and find it not eaten! What feverish last-minute repairs were made; what firm resolutions were passed never to let it happen again, only to be broken and the cycle to repeat itself. The moth population grew to its height in the latter half of the nineteenth century.

The population built up then because anything unwanted was pushed into a corner, or into the loft, a minimum of cleaning was done, and all the scavenging insects thrive. When the last tenant left in 1899, the moths were in no small degree responsible for the dirty state of the house. The house remained empty of man for the next ten years, and the moth population decreased very rapidly. It was no longer warm and the almost inexhaustible supply of dry litter — continually provided by man — ceased to come forward.

The population of the common cloth moth was almost nil in 1909, the year the next owners bought the place. Only a few moths were left in that constant source of material — the birds nests lodged in the eaves.

Because the clothes moths had proved such a continuous nuisance to man, they have had one if not reaching effect on him. The insecticide DDT was discovered while Müller, a Swiss chemist, was looking for new moth-proofing agents for furs. DDT is such a powerful insecticide and can kill so many disease-bearing insects (malaria mosquito, plague fleas, and typhus lice, to name a few) that millions, who would be dead from the causes, are now alive and healthy.

Would DDT have been discovered so soon had the clothes moth not been so persistent? Taking this into account, we can perhaps say that the moth had been beneficial to man, for it has killed down many murderous diseases, such as the Second World War, for the time in the history of war, more people were killed by bombs and bullets than by disease: truly, man has progressed.

An adaptable predator, the moth is plagued man for millennia, but moth chemicals threaten the animal's future.
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WASHINGTON NEWSLETTER

By Paul Mason Tilden

The opening days of the new Congress—the eighty-seventh such body deliberates on matters touching the life and future of the nation—sought the usual torrent of proposed legislation, contents of which are in gravity from a proposal to event the use of stop watches or other measuring devices in the postal service creation of a national peace agency. Many of the hundreds of bills dumped to the legislative hopper by House and Senate members will die in the dusty corners of legislative committees and subcommittees. Some will be rejected favorably and reach the floor Congress for examination, debate, amendment, recommital, rejection, or perhaps eventual passage. The percent of projected legislation arriving at is very last category will be small in comparison to the mass of proposed smoking during the session.

A number of the bills filed during the early months of Congress were concerned with conservation matters; several of these will be mentioned here.

The National Parks

The nation’s leading authorities on national parks remarked that use of our great primeval preservations was not in line with the trend followed in the past by the people whose parks brought into being such parks as Yosemite, Yavapai, or Grand Canyon. What he meant was that vast tracts of relatively unspoiled, and in the past, under three features: 1/5 or 6-inch mirror accurate to 1/2 wave + 3 matched eyepieces (60X, 180X, 360X) + 6x30 Achromatic finder eyepiece • Heavy-duty mount with setting circles • Raised & Plated eyepiece holder • Sturdy lightweight tripod.

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acres) to preserve an exceptionally fine bit of California coastal terrain. Here the subdividers are also beginning to stir, and several bills have been introduced into both House and Senate to accomplish a park while there is yet a chance to do so.

Several Senators have co-sponsored a bill whose purpose is to authorize investigation, looking toward possible preservation of a sizable number of lesser-known areas of great merit. Among these are Cumberland Island, Georgia; Channel Islands, California; Huron Mountains, Pictured Rocks, Grand Sable Dunes, and Sleeping Bear Dunes, all in Michigan; Fire Island, New York; Cape Flattery and Leadbetter Point, in the State of Washington; Mosquito Lagoon, Florida; Pigeon Point, Minnesota; DeSoto Island and Kiawah Island in South Carolina; Popham-St. John, Maine; Parramore Island, Virginia; and Smith Island. North Carolina. Senator Moss of Utah has added an amendment to this bill to provide for a study of Great Salt Lake leading up to some form of preservation for that remnant of glacial Lake Bonneville.

Once Again, The Wilderness

Without intention of treating a serious subject lightly, some people have suggested that future bills looking toward the establishment of a national wilderness system within our national forests, national parks, and national wildlife and game refuges be prefaced by Shakespeare's well-known line in King Henry V: "Once more unto the breach, dear friends, once more . . ."

During the course of the past five years, many different bills have been submitted to the Congress for the purpose of securing for the American people the "benefits of an enduring resource of wilderness." Not one of them has been passed as yet. Over the years, the bills have been revised to meet the objections of the National Forest Service, the National Park Service, lumber interests, mining interests, Chambers of Commerce, farmers, sheepmen, conservationists, and many others; all told, as incompatible a group of bedfellows as could gather under a single roof.

The new members of the Eighty-seventh Congress have barely become familiar with their surroundings before Senator Clinton Anderson of New Mexico, in behalf of himself and no fewer than thirteen other conservation-conscious Senators, had introduced S.174, a wilderness bill. At the time these lines were written, seven Congressmen had also introduced their own wilderness bills into the House. The general objective of all the bills: to establish and define some measure of congressional protection for outstanding wilderness tracts within the areas under the jurisdiction of various Federal agencies. To the present time, the classification and management of such areas has been a matter of administrative decision without the various agencies concerned.

Many conservation groups think the Congress has now gone as far as it can in meeting the objections of the man interests involved, and that any further watering will result in a downright meaningless piece of legislation.

Saline Water Conversion

One needs to be a little more middle-aged to recall the time when algae like "inexhaustible" or "limitless" were still applied to many of the natural resources of America. The kind of descriptive exuberance is seldom heard today, especially in regard to the nation's supply of a most vital mineral—pure water.

Statistical projections of the nation water needs—even into the reasonably near future—tell a crystal-clear story, we must either clean up and make usable the floods of deadly polluted water that return to the sea every day, or a sea must demineralize and use the water on the sea itself. Long-term-water use projections indicate that we will probably have to resort to both solutions.

For these reasons, the American public will hear more and more about a office in the Department of the Interior that has only lately emerged from obscurity—the Office of Saline Water until recently directed by Dr. A. Miller, now by Charles V. MacGowan. In 1952, Congress authorized the Secretary of the Interior to conduct research and technical work on the development of means for producing fresh water from salt or brackish water; with little pollution and a minuscule budget, the Office of Saline Water tackled the formidable problem of large-scale water conversion.

As a result of the Office's researches, saline water conversion is economical feasible today in areas of relatively high water cost; in the near future, it will very likely compete with orthodox water systems. A milestone was passed in 19 when the city of Coalinga, California—high-cost water area—installed a desalination unit to obtain its water supplies from brackish water. Since the several other hard-pressed cities in either installed, or have announced intentions of installing, saline water conversion plants; most recent was the city of St. Thomas, in the Virgin Islands which will build a plant to supply citizens with a daily average of 250.0
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As a matter of interest, the difference between a national wildlife range and a national wildlife refuge is one of the degree to which commercial exploitation is permissible. Oil and gas exploration and mineral leasing may be allowed within a wildlife range; ordinarily such activities are not permitted in a wildlife refuge.

The Rainbow Dilemma

The appointment of Representative Stewart L. Udall to the post of Secretary of the Interior, vacated by the outgoing Eisenhower administration's able Fred A. Seaton, was received by conservationists and their leaders with nearly unanimous satisfaction. It was widely felt that former Secretary Seaton's accomplishments in the fields of conservation and preservation were very considerable, in view of the somewhat less than ardent approach to those subjects taken by both the departing administration and the Eighty-sixth Congress.

One of the headaches inherited by the new Secretary of the Interior from the Eisenhower regime and the Eighty-sixth Congress is the vexing Rainbow Bridge controversy. Rainbow Bridge National Monument is a relatively obscure area of a mere 160 acres in the wild and broken canyon country of southern Utah—an area often called the nation's last bit of true western frontier. Fifty-odd years have elapsed since the Monument was established by a 1930 proclamation by President Taft to preserve the world's largest natural bridge. Since then a total of only about 12,000 strong-legged visitors have made the arduous, and sometimes dangerous, trek through the vast jumble of canyon and naked sandstone "slickrock" of the San Juan River country to feast their eyes and cameras on the stone rainbow.

When the Upper Colorado River Storage and Development Act was passed by Congress in 1956, conservationists made sure that it contained a commitment for the protection of Rainbow Bridge which is hidden away in a canyon of tributary of the Colorado River, from the encroachment of the water of Lake Powell, to be impounded behind the huge Glen Canyon Dam on the Colorado. Construction work on the Glen Canyon project commenced in earnest last year but conservationists were angered by the refusal of the Eighty-sixth Congress to make good on the intent expressed by the earlier session. I refused to appropriate any money at all for protective devices to prevent the monument from being flooded.

The conservationists have taken the troubles to Secretary Udall, who, incidentally, is among the very few American—who have visited the Bridge. Secretar Udall is sympathetic, although convinced that a water pool beneath Rainbow Bridge would damage it, and he included an item of ten million dollars in his Interior budget for the monument's protection. Time alone will tell whether the money will be appropriated by the Eighty-seventh Congress.

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COVER: This bumblebee was photographed by Dr. Alexander B. Klots, who, as Professor of Biology at City College, New York, and Research Associate, The American Museum. Despite the ubiquity of these insects, it is only in recent years that the mechanics of their flight has been studied. This is largely because their small size precluded such work until the late nineteenth century when developments in photography and various other specialized instruments. Intensive experimentation now has formed a basis for aerodynamic theories and muscle analysis, discussed by Dr. J. W. S. Pringle, beginning on page 2.

The American Museum is open to the public without charge every day during the year. Your support, through membership and contributions, helps make this possible. The Museum is equally in need of such support for its work in the fields of research, education, and exhibition.
THE UNITED STATES FOREST SERVICE has established a definition of a wilderness as any area of not less than a thousand acres with no road through it—an area, in her words, that a jeep cannot rattle through. By this definition, only two per cent of the land of the forty-eight States (excluding Alaska and Hawaii) can still be designated as wilderness. And, even in these dwindling remnants, there is pressure for yet more paved roads. If every town had a town forest, a section of wild land within a road, where shrub, swamp, pond, trees, and all wildlife, including predators, were left undisturbed—a place where those in need could revive their spirits by contact with the sources of life—it would be a boon to our race, for many people need the woods far more than they realize. At the knowledge that wild country is there, close at hand, will be a balm to frayed nerves. Between man and nature here is a deep affinity. Though mysterious in quality, its existence cannot be denied. A return to wilderness is tranquility regained; love of the wilder-ness brings excitement. But it is not just the affinity between man and nature that is important, for man craves challenge, one of the greatest experiences of life involve struggle with the elements. It is good to get soaked through and frozen and half-starved and exhausted and even lost, for these are the common experiences man's past. They are infinitely more important than protection and purity, for man is a battling animal. Our spirit needs primitive tension against wind and cold and storm and tide. Above all, we need it when young.

By Vermont farm land had been badly mutilated by destruction of timber, erosion of the topsoil, and drying of springs. It will be a long time before nature and proper handling can restore the good earth to full health and productivity. But it is on its way back. How fine it was other day to see a coyote stalk across one of my fields. To watch a fox circling some Canada geese that were spared to give him battle. How much better still, one night, when in a blizzard I came up close to a bobcat that killed three of my sheep. The farm suddenly seemed wondrously wild. Thank God for our predators—those that have the wit to survive against every machination of man. The balance of nature needs them. Man needs them. They add something that nothing else can provide—they make a place feel wild. Let us not seek their destruction.

Why does man wish to trap every last otter and mink and lynx and wolf and mountain lion and wolverine? What a pity that so many should fail to see the necessity of their existence. Usually, this is a failure to appreciate the full round orderliness of our natural world. What would a jungle be without a jaguar or leopard?

In the last analysis, the wilderness is disappearing because of the sheer pressure of too many people. Yet, in the beginning, man lived in the wilderness. Man's need for the wilderness goes back to the deepest core of his being. Fortunate are those who have discovered its infinite riches. Days in the open go on and on. They are measureless and filled with time. There is hardly a beginning or an ending. The greatest of all gardens are the gardens of the wild. They cost not a penny to maintain and they are the most beautiful. If we sit alone in the wilderness and look and listen and brood, after a while we merge with it. The desire to be "in tune with the universe" springs from our innermost being. The sense of belonging adds to our peace of mind. To acquire the wisdom to live in harmony with nature is our greatest goal. It transcends all other values. Wilderness is a temple that cannot be rebuilt like a bombarded cathedral. It is infinitely complex. Every part is interwoven on another. From the prowling predator to the enzymes in the soil, the ecological relationships are subtle and deep—yet so carefully balanced that the same ones may never be restored. To top a rise and find vast stretches of prairie inhabited only by the wild animals that belong to it—this is treasure unsurpassed. But it is treasure that we squander, for man rarely values what he has. It is only when it is gone that he begins to sense the depth of his loss.

We need a million million voices—not crying in the wilderness but crying to preserve it. Let us save every swamp and bog, forest and desert, canyon and mountain fastness that we can. It is the great garden of inspiration for our future. It is the elemental heritage of the human race. Let us save wilderness everywhere. It is our birthright.

"How lightly might this earth bear Man forever!"

Ichthyophiles are a motley crew. In fact, any politician who successfully put to use the rallying cry, "Fish lovers of the world, unite!" would find that he had acquired a constituency with nothing in common save devotion to some aspect of the finny tribe. Even this particular focusing of attention on a single type of animal is mutually exclusive in many instances. Fishermen frequently have little interest in fish beyond catching them, and even here the points of view of sport and commercial fishermen are poles apart. Fish fanciers live in a world bounded by their home aquariums, while ichthyophagous epicsures may hardly recognize a fish when not on a platter. Finally, there are those idealists who love the fish for itself, a variegated company that includes skin divers and other amateur naturalists, professional ichthyologists—and even curators of public aquariums!

Sheer size would account for some of the group's heterogeneity. In the United States alone, there are more than 29 million anglers, while an additional half-million people are associated with the commercial fisheries. Perhaps ten million American families keep goldfish or various "tropicals" as pets. Although the average American eats only a little more than ten pounds of fish during the course of a year (as compared with the 110 pounds consumed by a Javanese, for example), the national total—nearly 900,000 tons of edible fish—is hardly a quantity to be ignored. With the price of fish what it is today, taste, rather than economy, must account for the purchase of a good deal of this tonnage.

Such numbers of people with a more than-nodding acquaintance with fish would seem to warrant publication of a fair selection of books devoted to these creatures; but in truth, the number of really satisfactory popular fish volumes in English can be counted on the fingers of one hand—and I am excepting, here, only the dozen or so handbooks that deal adequately with the fishes of some part of the United States and make no pretense of furnishing a well-balanced account of fish life. Narrowness of interest may limit the market somewhat, but what better way to browse through these horizons than with a few attractive and well-rounded volumes? It is, therefore, an unusual pleasure to be able to introduce to NATURAL HISTORY's readers three new titles—all of them noteworthy additions to the meager but select list of toptight, popular books on ichthyology.

Earl Herald faced a formidable task in writing, for the layman, a single volume that covers all the world's living fishes. Present estimates put the number of species at some 30,000—more than all the different kinds of mammals, birds, reptiles and amphibians combined. Moreover, the bony fishes themselves show a greater variety of structure than any other comparable group of backboned animals, and one must also consider the completely different boneless sharks and rays, and the jawless lampreys and hagfishes. Altogether, fishes form a bewildering array, even to the specialist. As the world's authority on the classification of seahorses and pipefishes on the one hand, and as the organizer and host of an award-winning television show, "Science in Action," on the other, Dr. Herald fully realized how difficult it would be to transform pages upon pages of technical description into something understandable and interesting to the intelligent but untrained reader. Nevertheless, he did not try to evade the problem by ignoring the less well-known groups of fishes, the ones about which practically nothing is known except external anatomy and geographical distribution. He has accordingly treated all of the orders and most of the families of living fishes, and he has produced what is by far the most complete survey of them ever made in English, and probably in any language.

Because of his extensive experience with fish in captivity and in nature, both as head of San Francisco's renowned Steinhart Aquarium and as ichthyologist and diver-collector on several expeditions, Dr. Herald was able to enliven his text with exciting and informative personal anecdotes. Living Fishes of the World will not, however, be perused from cover to cover very often. It is rather, a reference work and, as such, volume to be browsed through repeatedly. Many pleasant hours could be spent reading about this or that group of fishes and looking at the associated illustrations. It took a world-wide search to find all the outstanding black-and-white and color photographs that so hand somely illustrate the book. Without question, they comprise the finest collection of fish pictures ever assembled.

Despite their tremendous diversity, many fishes at first glance look surprisingly alike. A trained eye is needed to spot the essential anatomical differences that distinguish similar species and there are some fishes so nearly alike that experts have to look twice before committing themselves. No one, no matter how expert, could ever hope to learn to recognize more than a small proportion of the thousands of different species. Therefore, to help one another identify fishes with which they have had no previous experience, fish taxonomists construct what are called "keys." The keys work reasonably well for the taxonomists, but the amateur who tries to use them soon finds himself hopelessly entangled with strange terms and concepts. The few keys that have been scientifically written for non-ichthyologists have been either quite limited in scope or not entirely successful, mostly because they were no more than modifications of keys extracted from the technical literature.

For twenty-two years, Alfred Perlmutter worked variously for the U. S. Fish and Wildlife Service and the Bureau of Marine Fisheries of New York State's Conservation Department. Many times he heard fishermen lament the lack of "practical" key, as they put it, that would enable them to identify unusual specimens that came their way. Fish

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men, both sport and commercial, as well as amateur naturalists with a marine bent, are at least as common along our Middle Atlantic seaboard as anywhere else, and the need for such a key in the area is correspondingly great. Guide to Marine Fishes is Dr. Perlmutter’s answer to that need. The key he has devised departs distinctly from his predecessors. It is entirely artificial—that is, it does not try in any way to reflect the natural relationships among the fishes, but arranges them solely for the convenience of the user. This is, in the reviewer’s opinion, a sine qua non of an truly non-technical key. The fishes are grouped according to external structures that are easily seen, and each is identified by an illustration. For example, when the key states, “Two dorsal fins,” the opposite page carries an outline drawing of one of the fish with a rows pointing to its dorsal fins. Below the contrasting character—in this case “Three dorsal fins”—similarly illustrated. At every step, the user will find that the choice he must make is clear, because both categories are illustrated, the one to which his fish does not belong as well as the one to which it does.

By means of this remarkably straightforward key, a person with no biological training whatever can identify any of the 260 species of fishes most commonly found along the Atlantic coast between Cape Cod and Cape Hatteras. So the rarer migrants and strays to a region have not been included, but those not encountered often enough to cause serious confusion. Since anyone who goes to the trouble of identifying the fish presumably would like to learn something about it, Dr. Perlmutter has provided a brief account for each species—color, distribution, size, economic importance, and general information in the latter including notes on its history, behavior, and ecology. But the raison d’etre of this book is its index or key, which should be the progenitor of a whole series of popular keys of fish from other parts of the world.

ANGLING is much more of an art than a science. If and when the river becomes true, fishing will probably come a much less popular sport than it is today. Nevertheless, there is plenty room for the application of scientific principles and data without the slight risk of taking any of the romance out of fishing for fun. James Westman believes angling ought to be an art based upon a science, but he is aware that angling, the one emphasized almost the exclusion of the science. Why Fish and Why They Don’t is his attempt to inject some science into sport fishing. Dr. Westman has been closely connected with the marine and freshwater fisheries of New York and New Jersey for many years. He knows angling and
not only from the point of view of conservation officials and fisheries biologists, but from the viewpoint of an individual fisherman. He has utilized the findings of scientists, including himself, to improve his catch; a number of the tips in his book were developed in this way.

The problem of getting fish to bite is a behavioral one. Very few persons directly applicable to fish-conditions have been performed, but, behaviorists who have accumulated large amounts of information, the proper interpretation of which might shed considerable light on the feeding reactions of fish. The best of my knowledge, most material has never been analyzed, so that a great deal of it has been published only in German. Dr. Westman hits only the high spots in his rather provocative presentation. There is no point in understanding accessory stimulation, a fish must bite. The implication is plain: the type of water and the way it is presented is more important than whether the fish is "hungry" or "in a feeding mood.

A considerable number of experiments also showed that fish act as if they have preferences for certain colors and patterns and, further, that it is difficult to change such a preference by training with punishment. Again, the implication is plain: the importance of lure design is critical. To exactly what fish are sensitive—seeing, hearing, smelling, and taste, the more we learn, the more we realize their extreme sensitivity. For instance, young salmon can smell an artificial chemical at a dilution of one ounce to 1,000,000,000 gallons of water (10^-9 gal.), and other fish can detect in water temperature of less than one tenth of a degree. Fish can learn very quickly, too. Dr. Westman found that largemouth bass will disregard a minnow attached to a hook and strike at one or two bad experiences, continue to snap up minnows.

In *Fish Bite and Why They Don't* written for anglers, the author describes the use of the seasons on fish and their ability, and describes fishing techniques of all sorts in detail. He concludes with a chapter on the preservation of fresh fish and the proper cooking of the fish. For many of his readers, Mr. Westman has chosen the right book for the scientific approach. It is interesting that they really could not use it.

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Garden City, New York
The fossil evidence allows deductions about these extinct animals' behavior

By H. B. Whittington

Trilobites are arthropods, one class of a phylum of invertebrate, segmented animals with jointed legs that contains among its living representatives such diverse forms as insects, spiders, centipedes, crabs, and lobsters. They are found in the oldest rocks of the Paleozoic era, at the beginning of the Cambrian period, some 600 million years ago. These animals, abundant in the early part of the Paleozoic era, decreased during the middle part of that era, and were even fewer in its younger rocks. The last survivors are found toward the end of the Paleozoic, about 250 million years ago. Trilobite fossils occur in a very wide variety of sediments—sands, silts, muds, and limestones. The other types of fossils found with them suggest that these sediments were laid down in relatively shallow, marine waters.

In the process of preservation, the original mineral matter in the trilobite's shell may be preserved, or there may be some addition to—or replacement of—this matter. Or the original material may be dissolved away together after burial and consolidation of the rock, leaving only an impression or mold of the shell. Study of the preserved shells of trilobites shows that the animal's body comprises a head region, followed by a thorax series of segments that articulated with each other, and a tail. The tail is formed by the fusion of several segments like those in the thorax; it may be smaller, equal in size, or larger than the head. The shell covered the head, and, on the underside, extended inward only a short distance from the margin. Since it is on the body, it is called an exoskeleton.
Trilobites

The trilobite's body was bilaterally symmetrical; it had a raised region extending lengthwise down the middle of the body and was flattened or downcurved on each side. It was this three-lobed form that prompted the name Trilobita for these animals. The raised middle region of the head was very prominent in some species and bore deep, transverse grooves reflecting the segmental lines. On each side of the head were two eye lobes. Across these eye lobes at around the front of the head ran an impressed line, the suture line, along which the shell split at the time when the animal molted.

Some trilobite shells are preserved with the body stretched out horizontally; in others, it is rolled up so that the tail tucked tightly in beneath the head. There were articulating devices between the movable parts of the exoskeleton, and the outer parts of the thoracic segments were beveled and could slide over one another. The animal could only roll or unroll in the vertical plane, however. Its raised middle region and the horizontal adjacent parts of the segments make it evident that no side-to-side curving of the body in the horizontal plane was possible.

Complete exoskeletons are the exception in fossil finds. It is more common to find only parts such as heads, individual thoracic segments, and tails, disarticulated from each other. The head itself is often separated into parts along the suture line.

Among the best-preserved trilobite shells known are some remarkable ones from Virginia (illustration, above). After burial in lime mud (which later became limestone), these shells were replaced by minutely granular quartz in a manner that preserved all the details with extraordinary fidelity. When blocks of these limestones—despite being Ordovician in age—are placed in dilute hydrochloric acid, the limestone is dissolved, but the replaced trilobite shells are unaffected and so can be freed from the enclosing rock without damage. The shells of any one species are not all of similar size, but...
form a graduated series. This series gives a record of the animals’ size growth—which took place by period molting—from that first formed, which was less than one millimeter in length onward. Articulated skeletons, like those of Cryptolithus and of Rem. pleurides, are extremely rare in the particular limestones, presumably because almost all the shells were dismembered as the dead animals drifted about on the sea bottom. Thus, six series are usually available only for individual parts of the exoskeleton, for example, the part of the head between the suture lines. Such a series exhibits the changes that took place outline and convexity, as well as the reduction in relative size of the spine.

In the process of a trilobite’s growth new segments of the thorax were developed in the tail portion. As they became fully formed at the front edge, they were released to become free and jointed between the head and tail. The number of segments thus formed is characteristic for each trilobite species. Trilobites that include six series have also been obtained from limestones in Utah and Nevada, whereas they are preserved also by silification. From other areas and countries in shales and siltstones, have come series of articulated exoskeletons, notable example being those described from Czechoslovakia more than a hundred years ago by J. Barrande.

It is extremely rare to find parts of a trilobite preserved other than the exoskeleton. This is presumably because the exoskeleton was strengthened by secretion of mineral matter, but the covering of the antennules and other appendages was not so reinforced. From a few localities, the most important being in North America, remains of appendages are known. An early discovery, announced in 1876, was made by Charles D. Walcott (later the Secretary of the Smithsonian Institution) in a limestone bed near Trenton Falls, N.Y. Spurred on by a memory of the enthusiasm of Louis Agassiz, Walcott obtained over 3,000 entire trilobites, in a few of which appendages were preserved. Walcott cut thin sections of these specimens and demonstrated clearly that trilobites possessed jointed appendages.

A few years later, W. S. Vallicl, then curator of the museum at Rutgers College, picked up a loose piece of rock near Rome, N.Y., which

Trilobites such as this Olenoides pair, with appendages visible as a thin film extending beyond the body, come from the Burgess Shale of British Columbia.
A trilobite with appendages preserved by having been infilled with shale. A patient eight-year search related to the discovery in 1892 of the Burgess Shale—a formation of middle Cambrian age near Field, British Columbia. A great variety of trilobites are preserved in these beds, including trilobites with the appendages actually visible as a thin film extending out beyond the margins of the exoskeleton.

No finds of comparable richness have been made since these early days, advances in our knowledge have come from the application of more refined techniques. An example of such an investigation is that made by Professor Leif Stormer of the University of Oslo, who came to the United States in 1931 and worked with fragments of Walcott’s original material from Trenton Falls. Stormer ground a series of sections, parallel to each other and a small distance apart, through an enrolled specimen. An enlarged drawing of each section was made, and each drawing was traced on a sheet of wax. The thickness of the wax sheets was proportional to the enlargement of the drawing and to the distance between successive sections. Each outlined wax sheet was then cut out and the sheets put together to form an enlarged model of the original specimen. The model gives an idea of the great amount of detailed information provided by Stormer’s work. This new knowledge, combined with a restudy of all previously discovered material, has resulted in a major advance in our knowledge of trilobites.

The head of this model shows the large plate (or hypostome), which lay underneath the middle region, together with parts of the appendages beside this plate. Most students of trilobites today believe that the animal’s mouth lay just inside the posterior edge of the hypostome, and that the stomach and other organs were enclosed in the capsule formed by the hypostome and the middle part of the head. The alimentary canal then extended back beneath the middle part of the body, terminating in an anus at the posterior tip. Stormer’s reconstruction of the underside of the body shows an enclosing membrane and a pair of similar appendages on each segment. Each appendage consists of a jointed walking leg with bristles at the tip. From near the base of the appendage rises a jointed branch that bears many fine
filaments. Under the head are four pairs of appendages; in front of them are the long, jointed antennules.

All investigations have shown that the trilobite's appendages were similar on each segment, and that none bore a claw or pincer for grasping and tearing food and passing it to the mouth. Trilobites probably fed, therefore, on minute organic particles suspended in the water or enclosed in the sediment of the sea bottom, this material being brought to the mouth by currents of water. The filament-bearing branches of the appendages may have been the main instruments in producing these currents. They probably also functioned as gills, and constant movement of the branches would have kept the gills bathed with fresh water.

The trilobite's appendages were attached by muscles to the convex middle region of the exoskeleton. Deep furrows in this region on the head, thorax, and tail formed projections on the inside of the shell for such attachments. Trilobites with smooth shells may show dark patches, which are believed to be corresponding areas of muscle attachment. The animal must also have possessed longitudinal muscles to effect its characteristic enrollment; these were probably situated in the middle region of the body.

It has been argued that trilobites like Isotelus (photo, p. 17), with its wide middle region and its relatively large tail, may have used a downward and forward stroke of the tail in swimming, as does the modern lobster. The bodies of these two animals are not comparable, however: the space for powerful muscles in the thorax and tail of this species of trilobite was not so great as that in the lobster tail.

Rigidity and strength must have been important requirements of the trilobite exoskeleton, since it was the framework upon which the muscular system operated. On the outside of the shell are ridges and grooves, pits, tubercles and raised lines, incorrectly called "ornament." These served to make the shell rigid, as do sheet-iron corrugations. In well-preserved specimens, many minute openings have been observed at the tips of short spines and tubercles. These are the ends of exoskeletal canals that led to sensory hairs or from glands beneath the exoskeleton. Such canals are also to be found disposed around the margins of the exoskeleton.

The main supply of the organic particles on which trilobites fed must have been close to the surface of, or within, the sediments of the sea bottom. We may reasonably conclude, then, that trilobites lived largely in this bottom region, swimming by means of to-and-fro movements of their appendage and also walking on, and digging or raking in, the bottom sediments. The antennules extended forward, exploring the region immediately ahead, as the eyes, with their many small facets, were well adapted to detecting movement in such surroundings.

Gradually, then, a picture of the life of these animals begins to emerge from a study of their anatomy. Trilobites must have made impressions in the soft mud of the ancient sea bottom as they searched for food; such impressions were later filled by sand or silt, they might be preserved as fossil casts, projecting from the underside of a layer of silt or sand now converted into rock. Just such tracks and trails are found in Paleozoic rocks: one sort of trail, call...
\textit{Ptychoparia}, is known from many con-
trasts. It is bilobed, with a prominent
an longitudinal ridge. On each
are obliquely directed ridges and
ves. In one example, clear impres-
s are believed to be those of an
imal's jointed appendages.

These trails are commensurate with
trilobites. They may be shallow, or
and pocket-like, or more or less
nous. Inward and backward
ments of the walking limbs of the
imal could have scraped out the hole
pushing out the material in the
ine behind them. Impressions in
ides of some of the deep hollows
believed to have been made by the
of a trilobite head and by spines
thoracic segments. The trails are
interpreted as shallow excavations,
or perhaps even tunnels, made
trilobites in the bottom sediment
ey passed through it in search of

Some of the deep pockets have
thought of as excavations made
the deposit of eggs, such as the
shoe crab \textit{Limulus} makes today,
we might expect that, occasionally,
individual trilobite would be
associated with such a trail—
remains of an animal that had
or of one that was overwhelmed

by a sudden inrush of sediments or
some other catastrophe. Yet, so far, no
such dramatic proof of this scientific
detection seems to have been found.
Thus, the interpretation of these trails,
although reasonable, is not positive.
In almost all cases, fossils are the re-
mains of animals that possessed hard
parts (skeletons impregnated with
mineral matter) that could be
preserved. Yet in these ancient seas there
were, in all probability, many inhabi-
tants that lacked such hard parts.
Conceivably, some of these fossil trails are
the enigmatic traces of just such soft
and now vanished animals.

A different type of track, from
Lower Cambrian rocks of Pakistan,
has recently been described by Dr.
A. Seilacher of Goethe University,
Frankfurt am Main. This track, \textit{Di-
morphichnus}, is abundant on the sur-
faces of the sandstone layers in which
the remains of trilobite shells are rare.
Nevertheless, the size and nature of
the track makes it probable that it was
made by the tips of the appendages of
a trilobite (photograph and diagram,
pg. 15). Dr. Seilacher considers that the
animal held itself diagonally to its di-
rection of progression, and that it dug
in the walking legs on one side to make

deep, short scars, while raking over
the surface with the legs on the other
side to form longer scraping marks.
Another example of a track, from an
Upper Ordovician siltstone of the Cin-
cinnati area, may also have been made
by a trilobite in motion.

Thus, compilation of all available
knowledge of the trilobite body,
combined with interpretations of the
tracks and trails, affords a picture of
how some trilobites may have lived.
Those like \textit{Isotelus}, smooth-shelled,
and with the tail similar to the head
in size, or like \textit{Dipleura}, which had a
narrower body and more thoracic seg-
mens, are presumed—because of their
smooth, elongate form—to have bur-
rowed into the sediments. There does
not seem to be any obvious correlation
between the type of exoskeleton and
the habit of raking the surface of the
sediments or making shallow excava-
tions in it. Such a mode of life seems
reasonable for such different trilobites
as \textit{Ptychoparia}, \textit{Flexicamax}, \textit{Crypt-
tolithus}, or \textit{Corabia}. The broad,
pitted fringe around the head of

13
Cryptolithus and the long, backward directed spines may have served to prop the animal up on the sea floor with its thorax extended above it, so that its appendages could have stirred up the mud. The broad border around and behind the head of Cordania may have supported the animal in a similar way. Despite this possible similar in habit, Cordania, which had eye sockets, has been identified by some authors as a trilobite, while others have suggested that it is more closely related to Cryptolithus.

Such spinose trilobites as Dicerurus, Apiarius (drawing, p. 101), and Ceratocephala can hardly have burrowed or dug into the sea bottom. They may, however, have rested with the level front and side edges of the head on the surface of the sediment, with their thorax stretched out and limbs stirring up the mud in search of food.

The large head plate—hypostome—of many trilobites was firmly braced against the remainder of the head, thus affording both protection for the main organs and points of attachment for muscles. The posterior edge of the hypostome was sharply folded, and in some species it bore spines, so that these trilobites could have dug into the mud with their hypostomes by walking backward. However, evidences of this behavior, in the form of trails produced by such activity, have not been recognized by paleontologists.

**Trilobites** of a particular body form, or of an otherwise related group, are in most cases not found exclusively in any one type of sedimentary rock. Smooth-shelled forms like Isotelus, for example, are found in reef limestone, shale, siltstone, and sandstone, but so is the spiny Ceratocephala. Some of these occurrences may result from the burial of an animal's shell in a sediment that was laid down in an environment different from the one in which the living animal resided. If the trilobite exoskeleton is not disarticulated and is well preserved, however, we may presume that it probably was buried close to where it lived.

Thus, clues to the ancient environment may properly be sought from the enclosing rock. Many cases in which this procedure has been followed suggest that particular species of trilobites possessed a wide tolerance of such environmental variables as depth of water, amount of light, temperature, and type of bottom sediment.
Although some species or groups of species have been observed to have favored one environment, although they were not confined to it. The Upper Cambrian trilobites of _Triarthrus_, for example, were abundant in dark, stagnant waters that were probably brackish in nature. Again, _Dipleura_ is a close relative of _Triarthrus_ from the same beds, but not exclusively in similar environments in which they probably dived. Trilobite remains are abundant in the Paleozoic reef rocks, and it has been claimed that one smooth-edged form inhabited the rougher zone of a particular reef, clinging to rock surfaces like a modern barnacle. Other examples are known of distinguishing features that are unique in reef rocks of different ages and geographic separation. Thus, there is evidence that certain trilobites were adapted to life in particular ecological niches in the ancient seas, but little evidence that most were restricted to a restricted environment. Possession of large eyes (in _Remacea_, for example) or absence of spiracles (in _Cryptolithus_) has been held to suggest a life spent in muddy or dimly lighted waters. Analogy is less convincing, however, does not point to any positive conclusions. The nature of the rocks that contain trilobite fossils suggests deposition in deep seas not more than a few hundred feet deep. Thus, we have no direct evidence that trilobites inhabited deep-water marine life. Yet, extremely similar forms (_Psycagnostus_ and _Dicerataspis_, for example) have been observed to be widespread. It is possible that these and other kinds of creatures inhabited the surface waters of the oceans, feeding on the microscopic floating plants or animals that inhabited the Paleozoic plankton? They browse amid floating mats of weed, like those of the Sargasso Sea. If we accept this mode of life, trilobites might have come to rest in widely scattered localities, and have been buried. In consequence, in very different types of sediments, we know, however, that newly died trilobites formed their first resting place when they were about a half millimeter in length. These tiny creatures slowly floated, like the larvae of crustaceans. The young may have existed in this stage for days or weeks, and, in that time, could have drifted far from the point where the eggs were laid. At a size of less than one centimeter in length in most species, trilobites became bottom dwellers in shallow water, and probably spent the remainder of their lives within a limited area. Thus, the wide geographical dispersion of particular trilobites may be explained as taking place during the larval stages, the adults dwelling on the sea bottom—not drifting in the ocean's surface water.

It has been said that spiny trilobites like _Ceratocephala_ and _Apinnurus_ were floating forms even in the adult stage, the spines inhibiting their sinking. However, we know nothing of the appendages of these trilobites and, as mentioned, the possession of a spiny exoskeleton does not preclude the possibility of bottom-dwelling.

Some modern arthropod species exhibit sexual dimorphism—that is, male and female forms that differ in size or in other characters. More than a hundred years ago, Barrande (in his great study of trilobites from Czechoslovakia already mentioned) observed a broad and a narrow form in certain species. Today, we consider these differences to be the result of distortion that the fossils suffered when the rocks enclosing them were subjected to various stresses. Other such examples among fossils are well known. Not all the cases of two closely similar forms coming from the same rocks can be so explained, however, and it may be that sexual dimorphism did occur in trilobites. If so, however, it was not universal: the cases are equivocal.

Although during the 100 million year period of the Cambrian, trilobites were the dominant animals of the shallow seas in kinds, numbers, and sizes, they did not have these seas to themselves. There were other aquatic arthropods in existence—types that, unlike the trilobites, were armed with pincers. However, the rarity of these arthropods as fossils suggests that they were not formidable enemies of the trilobites. From the earliest Cambrian onward, a succession of new genera and families of trilobites appeared, though the rate of extinction of trilobite groups was also high.

On balance, the picture is one of great evolutionary activity, of adaptation to a great variety of environ-
ments, expressed in a multiplicity of genera and species. At the end of the Cambrian and during the Ordovician period, this picture begins to change. New kinds of animals appeared. Previously existing ones became more numerous, and the animals must have competed with the trilobites for the food supply on and in the sea floor. Among these forms were the bivalved brachiopods and clams, and the snails, The nautiloids, molluscan ancestors of the modern Nautilus, were not only numerous and larger than trilobites, but probably had grasping tentacles and a powerful jaw. Such predators could have seized and eaten trilobites. But the capacity for enrollment may have afforded the trilobites some protection, and their spines must have made them an awkward mouthful. They may have lain partly buried in the bottom sediment, the projecting or stalked eyes of some species enabling them to detect nearby movement. Vegetation, clusters of marine animals such as sea lilies or corals, and crannies in reefs would also have afforded the trilobites places of concealment.

The evolution of many new kinds of trilobites in the Ordovician perhaps reflects adaptation to new environments in response to changing conditions. Yet it may be seen (diagram, left) that, toward the end of this period, the rate of extinction became greater than the rate of evolution of new forms. This is a pattern that continued through the animals' remaining history. Only a single group persisted through the Carboniferous and into the Permian. This decline—and the ultimate total extinction of trilobite—cannot readily be explained.

One of the mysteries of the evolutionary process is why such fate should overtake a group of animals that, for millions of years, were well adapted to their surroundings and continued to evolve new species until the close of the Paleozoic era. Phrases that imply “overspecialization” or “the senescence of the trilobite race” are neither apt nor meaningful. Ceratocephala has been regarded as a highly “specialized” trilobite, yet its exoskeleton is known from rocks ranging from Ordovician to Devonian age—a period of some 100 million years. This is clear evidence that types of animals well adapted to a particular environment may exist for an extremely long time within significant morphological change.

The competition for food with other groups may have played a part in the trilobites' demise. In addition, the Devonian fishes—among which jaw evolved for the first time—may have become trilobite predators. At present, however, there is no acceptable theory that explains the reasons for extinction of the trilobites.

New kinds of trilobites are constantly being found on all continents (although new information on trilobites and on appendages collects much more slowly). As the store of knowledge from new discoveries and improved techniques of investigation accumulates, we should be able to outline more precisely the natural history of these remarkable arthropods. For the present, we may agree with the late Professor Percy Raymond that perhaps the greatest contribution the trilobites have made to the world is the aesthetic pleasure the contemplation of their elegant shells gives countless collectors and students of fossils. But paleontology is a science that does more than enjoy its material: it also tries to bring extinct animals back to life. To me, it is more exciting to try to visualize the "elegant shells" as parts of living animals, inhabiting their particular niche in nature at a time so long ago that vertebrate animals had yet to evolve.
Golden-striped bass belongs to carnivorous marine family. As this species grows, stripes break to form short dashes. Imperial angel fish somewhat resembles the half-circle angel when young, but changes color patterns as it matures.
Half-circled angel fish, which eats animal and vegetable matter, is one of most characteristic of fishes inhabiting coral reefs. Lengths of the mature of the four different species pictured on these pages range from 10 to 16 inches.

BRILLIANT REEF FISH

Photographs by GENE WOLFSHEIMER

These fishes are typical inhabitants of coral reefs; as many as two hundred different kinds of them may inhabit the same reef. In no other habitat can such a variety of gorgeous creatures be seen, for although the birds and butterflies rival the fishes in number of species of resplendent beauty, few of these ever live so closely together.

The beauty of the many reef fishes is exceeded only by their diversity—in size, form, coloration, and behavior. Nevertheless, many of them are alike in the boldness of their patterns and brightness of the colors they display. This holds for one-inch gobies and six-foot parrotfishes, for the predatory, piscivorous basses and moray eels as well as small-mouthed browsers like the tangs and butterfly fishes. The existence of so many conspicuous species has raised questions in the minds of biologists, but there is only one hat concerns us here. Why, in a world where the great majority of the animals try to appear as inconspicuous as possible, both to escape their enemies and deceive their prey, do most of the fishes found around coral reefs seem so outdo one another in wearing the most striking garb?

There are some instances (for example, certain scorpion fishes) in which this could be considered a case of warning coloration displayed by many venomous or distasteful animals, which depend on each potential enemy to make an association between their unpalatability and their particular conspicuousness. But few reef fishes are venomous.

Some ichthyologists have come to the conclusion that, whatever the function of the salient coloration of reef fishes, it is not protective at all. It may be useful in species or sex recognition but, as far as attack by fish-eating predators is concerned, only the peculiar nature of the reef makes possible the survival of such conspicuous fre-swimming creatures. Coral reefs, riddled with crevices and caves, provide an agile fish with perfect terrain in which to lose a pursuer or hide from predators. Divers will vouch for this. The fishes are easy enough to see; in fact, some are insatiably curious, even to the point of tentatively nibbling at a diver’s skin. But try to catch one! The speed with which it dashes to the safety of the reef, disappearing around some corner or into some hole, is incredible.

On the other hand, a number of scientists have insisted that the very conspicuousness of the colors and patterns of reef fishes helps to conceal them. These men point out that against the busy background of a reef—with its myriads of highly colored, feathery, filamentous or arborescent animals, many of them in motion—the patches of strongly contrasting colors so characteristic of reef fishes actually make a fish less visible. Catching the observer’s eye, they prevent him from seeing the shape or surface of the fish itself. This disruptive coloration, as it is called, is dazzling. Even when photographed against a plain, artificial background, the fish requires a second, studied look to reveal all its piscine qualities. Especially noteworthy is the way in which the eye of some of these fishes is concealed by its incorporation in a dark stripe or bar.

Both of these points of view have evidence to support them, and it is probable that both hold true to some extent. Their relative importance will not be established until observers have spent many hours in underwater studies.

Mr. Wolfsheimer, a California photographer, is one of America’s leading raisers of hard-to-breed tropical fish.
The Flight of the
Complex anatomy is basis of control

By J. W. S. Pringle

Insects, in their mastery of flight, far surpass mankind's machines. Indeed, we know little about their flight mechanisms. Their small size and the speed at which they move their wings make even an accurate description of the wing motion difficult. The muscles that move an insect's wings have some special physiological properties, which are even less well understood than those of ordinary mammalian muscle. In the last ten years, however, considerable work has been done on insect flight by engineers, entomologists, and physiologists. This work has included studies of many different kinds of insects. For example, there are great differences between the flight of a butterfly and a gnat, yet there seems to be a sort of common plan, not only in the anatomy of wings and flight muscles, but also in the chemical reactions supplying energy for the muscles and in the nervous reflexes controlling them. An attempt will be made here to focus on the flight of the bumblebee—an insect so large and so common that anyone with a good microscope can check and extend the conclusions.

The bumblebee belongs to the order Hymenoptera, which includes the wasps, sawflies, and a large number of parasitic forms. Its flight machinery is very similar to that of the hive bee. Its two pairs of wings, like those of all insects, are very thin, elongated projections from the cuticle that covers the whole surface of the body. The joints and the sclerites, armallike plates that cover parts of the insect's body, are hardened regions of this continuous covering. Two of these main hardenings of the meso- and metathoracic segments are the tergum, on top, and the pleura, on each side. The wings project between them.

It has been known for over a hundred years that, among the higher insects, the main power for moving the wings comes from muscles that are not attached directly to the wings, but which stretch across the thoracic cage, longitudinally and dorsoventrally (page 23). By the alternate contractions of these muscles, the thoracic "roof"—the tergum—is raised or lowered, and the wings move down and
up accordingly. In the bumblebee, sclerites are arranged so that the main wing motion is diagonal—downward and forward, upward and backward. Particularly important in the bee is a subsidiary relative motion of the scutum and scutellum, two parts of the tergum. This motion serves to produce the figure-of-eight path of the wing tip and the automatic twisting of the wings that is required if aerodynamic lift is to be generated.

Consider the wing-stroke cycle that starts from the top of the beat, or end of the upstroke. At this moment, the large, dorsal longitudinal muscles begin to contract. These are attached behind a large sclerite, the mesophragma, which in the intact bee is entirely hidden underneath the meta-thorax and first abdominal segment. Taking one side only, the front end of the mesophragma pushes on the mesothorax and first abdominal segment. The middle of the mesothorax connects to the scutum: the result of the push from the mesophragma is to rotate the first axillary lever forward and downward. The mesothorax "crook" of the first axillary, in the diagram, connects with the leading edge of the forewing, and the wing is twisted so that its leading edge is depressed.

This twisting movement is initiated because the scutellum hits against the scutum. When this happens, the moving
continued contraction of the muscle lifts both sides of the thoracic roof—composed, as we have seen, of scutum and scutellum together—in relation to the side plates, or pleura, and the downstroke of the whole wing begins. Because this downstroke is preceded by the wing-twisting, the wing moves down in a pronated attitude, rather as if the lower arm and hand in a human were rotated in such a way that the palm turned downward.

Contrary to the description given in most textbooks, the wing's upstroke is not just a reversal of this sequence of events. Actually, the path of the wing tip on the upstroke is different from that on the downstroke, and the wing is twisted in a different way. At the beginning of the upstroke, it is the dorsoventral muscles that start to contract, lowering the thoracic roof on the pleura. The wing is connected to the roof through the first axillary, as has been noted. But it is also connected to the pleuron through the second axillary, and these two axillaries also articulate with each other. The initial effect of lowering the roof is to rotate both axillaries backward and downward, twisting the forewing in opposite fashion. As at the beginning of the upstroke, this initial twisting movement is limited by a stop. The stop is formed, in this case, by the backwardly directed arm of the second axillary, which fits into a socket located on the pleuron.

As the dorsoventral muscles continue to contract, further depression of the roof raises the wing, but it now pivots about a different axis; the wing tip performs its upstroke more horizontally, and is raised only later. The relative movement of scutum and scutellum has been reversed in this process and, as the wing reaches the top of its stroke, the whole cycle is repeated.

To summarize, the whole stroke cycle of the forewing can conveniently be considered in four phases:

(1) Movement between scutum and scutellum, rotating the first axillary forward and downward and the second axillary forward and upward. This promotes the wing and sets the axis of the downstroke movement more...
nearly horizontal, so that the wing tip moves downward more nearly vertically. This phase is limited by the scutum-scutellum stop. It is followed by:

(2) The downstroke.

(3) Initial lowering of the thoracic roof (tergum), rotating the first axillary backward and second axillary backward and downward. This supinates the wing and sets the axis of the upstroke more nearly vertical, so that the wing tip moves upward more nearly horizontally. This phase is limited by the stop between the backwardly directed arm of the second axillary and the pleural socket. The cycle is followed and completed by:

(4) The upstroke.

Having analyzed the mechanics of the wing-stroke cycle, we must now consider the muscles involved in flight. In all insects there are, in addition to the large, indirect muscles stretching right across the thorax, many other muscles that affect the wing motion. Some of these pull directly on the wing base or on the axillary sclerites; some insert on the tergum or pleuron near the wing base; some alter the elasticity of the whole thoracic box by pulling between its component parts. In primitive insects, and in some of the higher groups, especially dragonflies and beetles, some of these direct muscles are large and contribute part of the power for the wing strokes. But in bees, and nearly all Hymenoptera, all the power for the stroke comes from the indirect muscles: the other muscles are small, being merely adjusters that are used in the control of flight.

It is obvious that a bumblebee does not only fly forward at a steady rate; it can maneuver in the air with considerable skill. It has no auxiliary control surfaces, such as the individual feathers in the tails of birds, to enable it to do this; its maneuvers have to be produced by alteration in the form of the wing motion as a whole. There have been various attempts to understand how the many small muscles function to produce these modifications of wing motion, but many of them have failed to take into account one fundamental feature of the bee's flight system. In nearly all animals, muscles contract with the arrival of impulses through nerves connecting them to the central nervous system (brain or ganglia). When such a nerve impulse arrives, the muscle performs a twitch involving a brief contraction and relaxation. If nerve impulses arrive at a sufficiently high rate, most muscles do not have time to go through their contracting and relaxing cycle and, as a result, go into a steady contraction, or tetanus.

Mammalian muscles, for example, cannot perform separate twitches at a rate much above twenty per second. The flight muscles of grasshoppers and moths are faster, and can give separate twitches up to frequencies as high as ninety per second.

Apparently, no such muscles have evolved that are sufficiently fast to twitch more rapidly than about 100 times per second. Those insects whose wingbeat frequencies are higher than this (and in some flies the frequency is as high as 1,000 beats per second) have evolved a different method: the muscles that move their wings do not perform a single twitch on the arrival of each nerve impulse. Instead, they generate an oscillatory contraction, the frequency of which is determined by the mechanical properties of the muscle itself and by the load it is moving. This mechanism of rhythmic contraction is not limited in its speed of action, and insects possessing this sort of flight muscle can therefore move their wings at a much higher rate. Furthermore, it becomes unnecessary for the nerve impulses to be related to each cycle of the rhythm. In fact, in a bumblebee, with a frequency of 150 to 200 beats per second, the impulses to the flight muscles are quite slowly—only about 10 impulses per second—even when the muscles are contracting rhythmically 200 times per second.
controlling the form of the wing motion by an adjustable, steady pull on the various moving parts of the thorax and the wing articulations.

In the bumblebee, only the large, indirect dorsal longitudinal and dorsoventral muscles of the mesothorax have this particular structure and rhythmic function. All the muscles of the metathorax (the segment bearing the bumblebee's hind wings) and all smaller muscles of both segments are normal in appearance, and cannot contract during flight at the frequency of wing motion. The fact that these latter muscles must modify flight by a steady pull on the moving parts gives the essential clue to an understanding of their mode of operation.

What sort of changes in the wing motion are required to give control of movement through the air? Many of us are familiar with the control system used in a conventional aircraft. The three planes of space in which control is required are known as the pitching (fore-and-aft), rolling (banking sideways), and yawing (turning about a vertical axis) planes. In aircraft, the three forms of control are provided, respectively, by the elevator, ailerons, and rudder. An insect, however, has no auxiliary control surfaces, and in this respect is more similar to a helicopter. In a helicopter, control in pitch and in roll can be obtained either by tilting the whole plane of the rotor, or by arranging a system of cams so that the twist (incidence) of the blades is altered in different parts of the circle of rotation. Yaw control is usually obtained from an auxiliary propeller, as the main rotor turns in a horizontal plane.

Insects do not have rotating wings. The paths of the two wing tips, however, do not lie wholly in one plane, and it is this that makes auxiliary control surfaces unnecessary. In the bee, as in other insects, control in all three planes of space is obtained by the methods used in a helicopter in controlling the pitch and roll—alteration of the plane of wing vibration and differential twisting in different parts of the stroke. The articulations at the base of the insect's wings are of such perfect design that all these types of control can be obtained by the steady pull of small muscles on a number of different moving parts.

Unfortunately, we as yet have no high-speed pictures of a flying bee that could give evidence of the actual control movements used by this insect. But Dr. Richard Faust, Director of the Zoological Gardens at Frankfurt-am-Main, made some photographic studies of the bluebottle some years ago, and it is reasonable to assume that the results he obtained are also applicable to other fast-flapping insects. Dr. Faust obtained his photographs by fixing a fly by the top of the thorax so that it could still move its wings, and mounting it on the axis of a rotating shaft in various orientations. When the shaft turned, the fly tried to compensate for the rotation by altering its wing-twisting.

The first thing that became clear was that control movements occur during the downstroke; the upstroke never changed. During rolling movements, one wing was more twisted than the other in the later part of the downstroke; this is the phase during which the horizontal movement of the wing is greatest, and in which, therefore, the two wings generate different lift, and roll the fly back into a level attitude. In the yawing movements,
Control of flight motion is accomplished by alternating plane of wing vibration at different parts of the downstroke, as upstroke does not change. Paths of two wing tips are not wholly in one plane, so no auxiliary control surfaces are

the wings were differently twisted during the middle part of the downstroke; in this phase, the vertical wing motion was greatest, and the result of the different incidence on the two sides produced a compensatory yawing torque. During forward pitching movements, the wings on both sides had an equal and large supination twist at the start of the downstroke, when they were farthest up, and at the end of the downstroke when they were farthest forward. Thus, they acted together to resist forward pitching (drawings, above and below).

These experiments show how it is possible for a bluebottle with one pair of wings to control its attitude despite the lack of auxiliary surfaces.

The bee has a second pair of wings but these are tightly coupled to the forewings by hooks, and act as a single airfoil surface. Probably the hind wing muscles can alter the effective wing section of the whole surface by bending the back part up or down in relation to the front part.

The bee seems also to have developed a more efficient mechanism that
necessary. Diagrams across top show wing positions during formal flight, next strip demonstrates action in resisting a roll to left. In latter case, notice that one wing is more twisted than the other during later part of the downstroke.

be fly for altering the entire stroke plane, so that the wings can beat more horizontally or more vertically. Thus not only has it both kinds of the controls used in helicopters, but may also have another in the control of the wing section. No wonder its powers of maneuver are so efficient!

It is not easy to be sure exactly how all the small control muscles of the bee work, but careful dissection, coupled with a knowledge of the type of wing-twisting required, makes it possible to put forward some suggestions. Some of these are reasonably well established; others await confirmation by subsequent researches.

The mechanism of wing-folding is clearly understood. In both pairs of wings it is brought about by muscles attached to the knob halfway up the third axillary sclerite. When these muscles contract, the third axillary turns about its axis and pivots about its base, carrying the hind part of the wing upward and backward. The wing turns about the second axillary, and the base of the leading edge disengages from the upper arm of the first axillary. This is the typical method of
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wing-folding found in all insects that perform this movement.

Unfolding at the start of flight is not performed primarily by muscles attached directly to the wings. It results from the simultaneous tonic contraction of both dorsal longitudinal and dorsoventral indirect muscles, which strain the whole thorax so the wings unfold. Tests on a freshly killed bee show that for the unfolding movement to occur properly it is also necessary for the dorsal longitudinal muscle of the metathorax (the retractor of the mesophragma) to be tonically contracted, so that the mesophragma is not allowed to move forward. It is interesting to remember that, in evolution, this muscle must have been responsible for the downstroke of the hind wing. The nervous mechanism originally responsible for keeping this muscle active during flight still operates, but its steady pull during flight now serves to keep the wings unfolded, and to transmit passively to the hind wing some of the power that is produced in the dorsal longitudinal muscle of the mesothorax.

The path of the wing tip can certainly change during control movements, so that the whole cycle of movement takes place with the wing pulled more or less forward, and in such a way that the figure-of-eight path alters in shape. The forward position of the wings is probably produced by the basalar muscle, which pulls through a ligament on the leading edge. The alteration of the shape of the figure-of-eight is a more complicated process, involving a relative change in the magnitude of phase one of the basic wing-stroke cycle in relation to phase two. Phase one, involving the forward movement of the scutellum against the scutum and a rotation of the first axillary sclerite to produce pronation, is normally terminated by the operation of the scutum-scutellum stop. A muscle attaches to the scutellum in such a way that its contraction will tend to resist the movements of phase one and allow phase two to start earlier. This must have two effects: the wing is carried forward rather than downward in the early part of the downstroke, and it moves forward with a high angle of incidence, because of its lack of pronation. This is exactly the form of wing motion Faust found compensating for forward pitching rotations in the blue-bottle, and it is reasonable to conclude that scutellar muscles are mainly used by the bee for pitch control.

Faust did not study the changes in the path of the wing tip during compensatory control reactions, but there is some evidence on the point from some experiments on the stable fly by F. S. J. Hollick in 1940. He found that a fly in still air moved its wings downward at the beginning of the downstroke and had a tendency to pitch forward. In a current of air, the wing tip path at the beginning of the downstroke was forward and the pitching tendency disappeared. Probably this compensation was being controlled by a muscle analogous to the bee's scutellar muscle for pitch control.

Control of yawing movements in the bee is probably done by the subalar muscle of the forewing, which pulls through the subalar sclerite on the lower arm of the second axillary and on the base of the third axillary. This action should tend to increase the wing's drag during the downstroke, especially during the middle part, when vertical velocity is greatest.

Control of rolling movements in the bee, unlike that of the fly (which has only one pair of wings), is probably done by the muscles of the hind wing. We have already noted that the airfoil surface in the bee comprises the two wings, tightly coupled together, the power for the stroke being delivered entirely into the forewings. The muscles of the hind wing, comparable in size and structure to the other slowly contracting muscles involved in the control of flight, must be mainly responsible for the changes in wing section by altering the relative attitudes of the fore- and hind wings. During the downstroke, the whole surface will be more convex if the hind wing is relatively depressed, and this shape will contribute more lift during the later part of the downstroke. A different camber on the two sides of the body will generate a rolling torque. The muscles involved on each side are the subalars of the hind wing and the indirect dorsoventrals of the hind wing, pulling the wing down or up, respectively. Both are well developed in the metathorax and function antagonistically, thus delicately controlling this important feature of the mechanism.

The most remarkable special feature of the wing articulation of bees is the structure known as the axillary lever. It is clear that the function of this structure is to control the power of flight and the amplitude of wing movements, with some control of the stroke plane (the angle to the horizontal of the average path of the wing tip). The German entomologist Stellwaag noticed in 1916 that bees seem to make much use than do other insects of changes in the stroke plane, and we now know that this is an incidental feature to changes in the amplitude of beat. The axillary lever is, indeed, a lever in the true sense. It pivots about the front end of the mesophragma, and has a short arm with a socket in which rests a pointed projection from the pleuron and a long arm, directed backwards, that bears a downward-pulling muscle at its end. When this muscle contracts, its force is enormously magnified by the lever action; a rather small tonic muscle can thus displace the mesophragma backwards and move the main wing articulations relative to each other, in spite of the fact that the whole power of the large indirect muscles is being transmitted through these structures. Like all muscles, the indirect wing muscles deliver more power when they are stretched, and the amplitude of the wingbeats is therefore increased. At the same time, the axis about which the downstroke (phase 2) occurs is tilted, and the stroke plane becomes more nearly vertical. This must have the effect of increasing the forward component (thrust) of the downstroke's aerodynamic force in relation to the upward component (lift). The action is like that of an accelerator; instead of just hovering, the bumblebee is able to move forward through the air.

One of the most interesting aspects in a study of insect flight is the continual discovery of new ways in which the aircraft designer has unknowingly copied these accomplished fliers. Some years ago, instrument engineers produced an aircraft blind-flying device that works on the same principle as the fly's gyroscopic sense organs, known as the halteres (Natural History, February, 1943). Now there is a helicopter in which control of forward motion is achieved by what is, in essence, the bee's axillary lever.
Depressed forewing, with axillary sclerites at base, is articulated, above. (1) and (2) slide over each other, and (4) is tied to (1) and (3). Arrows indicate the points which sclerites articulate to suspend wing from thorax.

Natural position of sclerites is seen from beneath wing, below. Mesophragma's push at start of downstroke rotates first axillary, pronating wing. On upstroke, the rear arm of second fits into pleural socket, changing axis of movement.
SKY REPORTER
Isaac Newton, gravity, and optics
By Simone Daro Gossner

ARIStOTLE had taught that a body is kept in motion by the constant application of a force and that it comes to rest when the force subsides. Galileo’s studies of the motions of falling bodies constitute the first challenge to this erroneous concept; although he did not express it in these terms, his results imply that, if a body is not subject to the action of any force, it is either at rest or traveling at constant speed along a straight line; whereas an applied force would deflect, accelerate, or retard its motion (these conclusions were eventually formulated by Isaac Newton).

Concern for the cause of celestial motions was also evident in Kepler’s work. In Harmonice mundi, he intimated that planets are kept in orbit around the sun by some power emanating from that body. This was, however, a purely philosophical concept, without bearing on his empirical determination of the shapes of orbits. Nevertheless, the question was definitely in the air from the beginning of the seventeenth century. If its solution eluded Kepler, this was partly because the Lutheran mystic did not have at hand the necessary mathematical tools.

Isaac Newton (born in 1643, the year after the death of Galileo) devised a primitive form of calculus that became the key to his success. Driven to the country by an outbreak of the plague in London, in 1665, he devoted his enforced leisure time to a study of the motion of the moon. His approach was prompted by an analogy with the fall of objects on earth: anything dropped falls vertically to the ground, but an object tossed laterally (such as a ball in play) describes an arc before reaching the ground; and the stronger the toss, the longer the arc.

Conceivably, if the object could be imparted enough speed, its trajectory could be lengthened to the point where it would no longer return to earth, but would remain in orbit around it. Before he could apply this concept to the case of the moon, the young Newton was faced by another problem. If, indeed, an object falls to earth because of the latter’s gravitational pull, how much remains of this pull at the distance of the moon (in other words, how much attraction has to be counteracted by the moon’s lateral—orbital—speed)? At this point Newton had to make an educated guess, and the measure of his genius lies in the fact that he guessed right.

Having assumed that planets are kept in orbit around the sun by a similar gravitational pull from that body, noted the remarkable relation expressed in Kepler’s law of planetary motion (Sky Reporter, May, 1961), namely, that the square of a planet’s period increases as the cube of its mean distance from the sun. This means, of course, that—the farther it is from the sun—the less is the orbit speed of a planet: a first indication that the effect of gravitation lessens with increasing distance. This also means that this reduction of gravitational pull does not occur in direct proportion to the distance itself. Newton guessed that its effect varies inversely as the square of the distance and set about to verify his hunch.

Returning to the earth-moon system as a model, Newton used his newly invented calculus (which he called “math of fluxions”) to compute what orbital speed the moon should have to counteract the earth’s attraction. His result differed by about 10 per cent from the observed value, because of this discrepancy and because of a mathematical difficulty, which he had not resolved to his satisfaction. Newton did not publish his theory at that time.

A few years later, a group of French scientists set out to redetermine the length of the earth’s radius. They found that earlier estimates had been in error by about one-sixth.
Poor lenses of early period meant that refracting telescopes, such as Huygens' 123-foot model, left, had focal lengths of vast dimensions.

Giant refractor, built at Danzig for Hevelius, spanned 150 feet between objective and eyepiece. A clumsy rig, it was seldom used.

The adopted value. Since the moon's distance is known primarily as a function of the terrestrial radius, here lay the source of the discrepancy in Newton's results. When he returned to his problem, Newton soon arrived at a complete verification of his theory. As further convincing proof, he was able to show that Kepler's laws may be derived mathematically from his own law of gravitation.

No less important to the progress of cosmological ideas were Newton's discoveries in the field of optics. Observing, as Grimaldi had done before him, that a glass prism disperses a ray of white sunlight into all the colors of the rainbow, Newton proved experimentally that these colors are elemental components of white light, and he deduced their dispersion to the fact that each color is refracted differently. His conclusions were the first step toward the development of astronomical spectroscopy, a measurement technique by means of which it has become possible to study the composition and temperatures of stars.

Until Newton's time, the only telescopes in existence were refractors; that is, combinations of lenses. Their major drawback was a defect called chromatic aberration, caused by the fact that the edges of the lenses act as many prisms, and the resulting images appear surrounded by a rainbow-hued halo. In modern instruments, this defect is removed by combining lenses with different refractive indices that compensate each other. In the seventeenth century, however, the only way astronomers knew of minimizing chromatic aberration was to increase the focal length of their telescopes. At the same time, they craved larger lenses in order to observe fainter stars. But, for every inch added to the diameter of the lens, the focal length grew by several feet. As a consequence, refractors of that epoch became so long and unwieldy that it was no longer possible to encase them in solid mountings. Typical of these monstrous rigs were the instruments erected by Christian Huygens (above, at center) and Johannes Hevelius (above) in which objective and eyepiece were aligned by a simple rod or a length of string.

Newton mistakenly believed that there was no other way of correcting refractors for chromatic aberration. In order to construct telescopes of more suitable size, he saw no alternative but to replace lenses by mirrors, which merely reflect light without color dispersion. Although the idea of substituting mirrors had been advanced by others, he was the first to design and build a workable model.

Ordinary glass mirrors were unsuitable because their reflective coating is applied to the back of the glass, which the light must still penetrate (and thus be refracted) before it is reflected (the process, used in modern telescopes, of depositing a film of silver on the front of the glass is a nineteenth-century invention). The only other possibility was to use a metal mirror, and Newton's success derived from his selection of a suitable alloy, the so-called "bell metal" containing six parts of copper and two parts of tin, to which he added one part of arsenic.

His first telescope (above, at left) was only six and one-half inches long. The principal mirror, at the bottom of the tube, was shaped to a spherical surface, and the reflected light rays were further deflected to the side of the tube by a small, secondary mirror. The performance of Newton's instrument was far inferior to that of its contemporary refractors, but its principle aroused considerable interest among scientists. In the centuries that followed Newton, large reflecting telescopes were to become the foremost instruments for the astronomical exploration of the universe.
THE SKY IN AUGUST AND SEPTEMBER

From the Almanac:

<table>
<thead>
<tr>
<th>Phase</th>
<th>Date</th>
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<tr>
<td>Last Quarter</td>
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<tr>
<td>New Moon</td>
<td>August 11</td>
<td>5:36 A.M., EST</td>
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<tr>
<td>First Quarter</td>
<td>August 19</td>
<td>5:52 A.M., EST</td>
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<td>August 25</td>
<td>10:14 P.M., EST</td>
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<td>September 1</td>
<td>6:06 P.M., EST</td>
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<td>September 9</td>
<td>9:50 P.M., EST</td>
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<td>First Quarter</td>
<td>September 17</td>
<td>3:24 P.M., EST</td>
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<tr>
<td>Full Moon</td>
<td>September 24</td>
<td>6:34 A.M., EST</td>
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The sun will cross the celestial equator from north to south on September 23 at 1:43 A.M., EST (equinox). Autumn will begin on that date in the Northern Hemisphere.

For the visual observer:

Mercury, in the morning sky at the beginning of August, will be in superior conjunction on August 14 and will enter the evening sky on that date. It will remain an evening star throughout September and will set about an hour after the sun all month long. Poorly placed for observation in August and most of September, it will become more favorable for a few days about September 28, the date at which the planet reaches its greatest eastern elongation.

Venus will rise at 1:45 A.M., local standard time, on August 1, at 2 A.M. on August 15, at 2:30 A.M. on September 1, at 3:00 A.M. on September 15, and at 3:30 A.M. on September 30. It will be conspicuous in the eastern sky at sunrise. Venus will pass south of Castor and Pollux in the constellation Gemini at the end of August.

Mars (+1.9 magnitude) will move from Leo to Virgo in August and will remain in Virgo throughout September, passing north of Spica about September 20. An evening star, it will set soon after the sun during these months and will be difficult to see, very low in the western sky.

Jupiter (−2.2 magnitude) will be found in Capricornus in August and will move to Sagittarius in September. In the evening sky, it will cross the meridian at about 11:30 P.M. on August 1, at 10:30 P.M. on August 15, at 9:30 P.M. on September 1, at 8:20 P.M. on September 15, and at 7:20 P.M. on the final night of that month.

Saturn, in Sagittarius (+0.6 magnitude), will be approximately five to six degrees west of Jupiter in August and September. Therefore it will cross the meridian each day about twenty to twenty-five minutes before Jupiter.

The Perseid meteor shower will reach its maximum intensity on August 12, one day after New Moon. Barring inclement weather, as many as fifty meteors per hour may be seen by an alert observer away from city lights.

Eclipses:

An annular eclipse of the sun will occur on August 11, but the path of the annular phase—in which the dark disk of the moon is seen surrounded by the bright rim of the sun—will lie entirely over the South Atlantic Ocean. Partial phases of the eclipse will be seen on the southeast coast of South America, in South Africa, and in Madagascar.

A nearly total eclipse of the moon will be visible in the continental United States on the evening of August 25, beginning at 8:35 P.M. and ending at 11:42 P.M., EST. On the West Coast, the moon will rise already partially eclipsed.

On the preceding pages, Mrs. Gossner offers the seventh in her 1961 series on the growth of cosmological concepts.
con su hijo son fray de ayala sale de sopre un cielo a causa de las Reyn de Lima a Barquenta aguagre y salepo tree esciendo y camina en bien no

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OF ALL THE HIGH CIVILIZATIONS of pre-Columbian America, that of the Incas has received the greater share of public attention. Here were not only civilized folk, with cities and temples, irrigation and kings, but also a utopian state that attracted curiosity from 1534 on, when the first European chroniclers began to publish their impressions in Seville. Here was a kingdom "where the government insured the individual against every sort of want and, in return, demanded heavy tribute..." Over the years the notion has grown that Inca society, when met by the Europeans, was a kind of welfare, if not socialist, state.

Modern anthropology has been re-examining this commonplace in the light of recent ethnographic learning about similar transitional societies elsewhere, particularly those encountered in Africa and the Pacific.

These studies show that our vision of the Inca is distorted and that the blurring has been compounded because we see the Andean world through two alien lenses: that of the sixteenth-century European soldiers, priests, and administrators, and that of the Inca elite, who acted as the invaders' guides and confidants.

The most immediate limitation has been the absence of Andean versions of what the local peoples were like. We have no codices for the Aztec like the Aztec, Zapotec, or Maya books written before the European invasion; no shorinical writing has been discovered yet in South America. The political and intellectual decapitation of the new state by the Europeans was so swift that no interviews with the Amanta—the learned and effective men—have been preserved. All we have are versions of the Cuzco court clique and the military, and even those were recorded imperfectly by impatient, ethnocentric strangers. Before it is here is one of the few exceptions: a document about Andean man and his world written from the inside by one such man and illustrated by him with 400 drawings. This document is a unique source on Andean life before 1532.

Nobody knows how a 1,200-page "letter" by an Andean Indian, written to the King of Spain about 1615, found its way to Copenhagen. Some think it was in a collection of American curiosities bought in Madrid by a seventeenth-century Danish Ambassador; it remained unknown to students of the Inca for three centuries, until found in 1908 in the Royal Danish Library by Richard Pietschmann, a German scholar. Guaman Poma's manuscript, called Nueva Corónica y Buen Gobierno (the New Chronicle and [a] Good Government), was mostly a cry of anguish, a petition to the all-powerful King overseas to look at what his men were doing in America, to look at what they had destroyed.

Poma was born soon after the European invasion and grew up in the early decades of the colonial regime, a period of rapid decrease in the Indian population, years of civil wars among the invaders themselves, and of massive deportations to the silver mines of Potosí and Huancavelica. Much of his letter grieves for the vanished Andean order and complains of the iniquities of sixteenth-century colonization. But it is also a constructive document; most of it is devoted to plans for a "buen gobierno," a good government Poma thought could still be devised by combining revived Inca social and economic organization with Christianity and some beneficial aspects of European technology, such as growing grapes and making wine.

This article does not deal with Poma's dreams and plans for the future. It concentrates, instead, on the first third of the document, in which the Andean author tells the Spanish King of the glories of the pre-European past, the agricultural cycle of the peasant community and its relation to religious festivals, the distribution of chores and citizens' duties by sex and age, and the various ethnic and local groups submerged by the Inca conquest. He also provides a gallery of portraits and profiles of various Inca queens, victorious generals, and kings. Some of his facts are available from sources discovered and published before Poma; in fact, much information in these other sources is more detailed and more reliable than his. The Spanish used by other authors is more elegant, unmarrred by the many Quechua words that pepper Poma's text. And yet there are two contributions he makes that are basic and have remained unequalled: the drawings supplementing
the text and his picture of what Inca civilization was like locally, away from Cuzco, the imperial capital.

Guaman Poma was aware of some of the books preceding his own. He had learned to read and write from a half-brother, a priest, and in later years he accompanied various clerics on their idol-burning missions through the Andes. With at least one of these missionary writers, Martin de Muria, author of a history of the Inca kings, Poma had considerable contact: there are interesting parallels between the works of these two men they share with no other source. One of Poma's drawings has been found recently among Muria's papers at the Apsley House Library in London. Poma's references to Fray Martin are bitter and sarcastic; his own work is titled Nueva Corónica, the new chronicle, to distinguish it from that of Fray Martin. Like other Peruvian Indian and half-Indian writers at the turn of the seventeenth century, Poma was moved to write his account not only because of his people's suffering but also because of the distortions that appeared in reports made by European observers.

One of these distortions lay in the ready acceptance by Europeans of an Inca version of the pre-Incaic past. Although the Inca state had begun its expansion less than 100 years before 1332, Cuzco ideology claimed that all had been chaos and savagery in earlier days, Andean institutions were claimed to have been magnanimous grants to barbarians by the Cuzco crown. We know today from archeology that all this is untrue; for literally thousands of years before the Incas, people in the Andes had known how to irrigate the desert, make lovely tapestries and ceramics, and build fortresses, cities, and roads. All this was also known to many local lords and their descendants, defeated but recently by the Inca and still remembering their own past prominence and accomplishments. Poma claims direct descent from one of these local dynasties, the Yaravíllcas of Huánuco; his book is meant to set the record straight in more ways than one—he promises us "the history of the first kings... of our ancestors, grandparents and my parents, who were lords before the Inca...."

Civilization, Poma claims, is pre-Incaic. In a very personal amalgam of biblical legends with local Andean traditions, Poma sees a four-stage scheme that puts the descendants of Adam and Eve in America 7,000 years ago.

In the first stage, which lasted 800 years, the inhabitants—although already distinctly Indian—are still somewhat like "their father Adam"; like him they had "begun to work, to plow." But these early folk "did not know how to do anything," neither weave cloth nor build houses. They dressed in leaves and straw, and they lived in caves. Wandering through strange country, full of wild animals and dangerous spirits, "they lost their faith and hope in God, the word and commandment all was lost, and so they too were lost although they did have a small shadow of knowledge of the Creator of men and of the world and the sky, and Him they worshipped and called God...."

Throughout these four evolutionary stages this small shadow endures; it is only in the final, Inca period that idolatry and sun-worship make their appearance.

By the second stage, which lasted 1,300 years, men were dressed in furs and "they built small houses that looked like ovens." Agriculture had developed: terraces were built and irrigation brought water to the maize fields.

The third era was almost as long (1,100 years) and, in
Poma's scheme, it is the most important. Men learned to weave both elegant and ordinary cloth; their houses were of stone with thatch roofs. The coast and other warm places were peopled, and "roads were opened for them, which one follows today." People raised many llamas and began looking for gold and silver. There was law and order; boundaries were marked on "properties and lands and pastures and maize fields." If the people proved to be varied in custom, language, and clothing, "it is because of the land which is so broken up and twisted." They raised kings and lords, "of the legitimate kind, descendant from the uari uracocha people," of the first era. There was much charity in the land—"this is why they are in the public plaza" Poma writes of one picture—so all could partake of hospitality, and they sang and danced.

The description of this period ends with a prologue; "Look, Christian reader, look at these people, the third men. . . ." It was the start of a golden age in which, according to Poma, most of the accomplishments usually attributed to the Inca, particularly welfare features, were present long before Cuzco was even heard from.

The fourth period was the longest—it lasted 2,100 years. War became common and people had to withdraw to hilltops and build fortresses; they conquered each other's lands and took each other's women, and were led by valiant captains who could change themselves into lions and falcons. This is why today their descendants are called Guaman—falcon, and Poma—lion. The good system set up in the third era was still operative—"pilgrims and foreigners, orphans and the sick and those who had nothing to eat" could still eat in the public plaza—"no other nation has had this custom" and "if only they did not have these three vices—drunkenness and war and taking each other's lands away," one could think of them as "holy men."

It is in this fourth and last pre-Inca period that we meet the Yarowilla, whose descendant Guaman Poma claimed to be. Their home was near Huanauco but they reigned over vast territories beyond. Their ruler "had a higher crown" than others and even in later days "he was feared by the Inca. . . ." A genealogy is provided but the details are few, and we never learn how this mighty lord's descendants came to fall so low only a generation later.

After 5,300 years, these four ages of the world end with the ascendancy of the Inca dynasty in A.D. 300. Poma explains slyly the rise of idolatry and sun-worship at this time: the first Inca had no legitimate father, so his mother said he was an offspring of the Sun.

One of the most exciting accomplishments of Andean civilizations was their domestication of a wide variety of plants and animals well adapted to the extreme climate in the high Andes. The potato, the alpaca, the guinea pig, and the llama are well known, but scores of other plants—grains, roots, tubers, vegetables, and herbs—were also domesticated by Andean man, although they have not yet found acceptance in other parts of the world. At the extreme altitudes where man lives in these mountains, each change of 300 to 400 feet brings with it a new microclimate, and new crops must be found that survive the rigors of weather at 11,000 or even 13,000 feet and still bear fruit. Poma gives us a calendar of the agricultural practices. He shares the highlander's predilection for maize. Although maize is frequently very hard to grow at Andean
part of peasant obligations to the Inca state and were set to state warehouses to be woven into soldiers' clothes.

The third period in the Andean calendar is called Poma "the month of water shortages and the watering of maize." A warm-weather plant of general Near World distribution, maize was particularly in need of artificial watering; in fact, it can rarely ripen without irrigation and in Andean circumstances requires a good deal of special, almost gardening care. Poma reproduces fragments of a prayer with which one supplemented irrigation: "... send me water from the skies, look at me your son, have compassion." There seems to be little relation between the well or reservoir in its drawing and the linear forming squares on the ground in several of these pictures. It is nevertheless quite likely that the lines represent irrigation ditches, particularly as they are absent from the December drawing, which shows the planting of oca (O. ollu tuberosa), a major staple in the highlands. Potatoes and other locally domesticated tubers were grown without irrigation on fallow land. They formed a separate or quite different type of Andean agriculture, readily distinguishable from that of maize. In this sense Poma's December illustration is an important bit of data—most early writers were so obsessed with the difficulties and prestige of growing maize that they virtually ignored local staple.

By January the rains are falling everywhere in the Andes and the growing plants must be hilled, while early potatoes can already be harvested. The rainy season has its own dangers: food reserves are low and sickness is common. Poma writes that "the old and the children are dying." In February and March, more of the tubers—the peasant crop—can be harvested, and the corn is high and cobs. Young people spend day and night in the fields guarding the crops, which finally begin to ripen in April. Poma points out that theft reaches its peak this month since human thieves join animals in threatening what would otherwise be the beginning of a happy harvest season.

Aymaray—the song of the harvest—is the name of the next month, when the maize should be dried, husked, and deposited in warehouses, and "the seed kept and the maize for food and the poorest for beer." In June, larger potatoes can be dug up and the early ones plant to produce a third crop. Since the rains have stopped, this is also a good time to clean the irrigation ditches.

Work must begin at this time says Poma, and "all authorities who will see this work" are urged to take care that early potatoes and maize be planted along with the slow-ripening varieties to make sure no one goes hungry while waiting for the major harvest, which in the high Andes is eight or nine months off.

In the second month, that of the September equinox, young maize shoots appeared, and so did the dangers that threatened this delicate crop: frosts, predatory animals, and drought. Parrots and other multicolored birds, attracted by the planting, were killed by boys with slingshots. Feathers harvested during such scarecrow duty were
October: chase pests from field.

November: irrigate fields.

December: plant oca, a staple.

January: weed and hill corn.

February: harvest early potatoes.

April: thieves attack crops.

May: harvest the maize crop.

June: harvest the potatoes.

July: the crops are stored.
be saw in the census the visible symbol of this regularity. Poma's version of the Inca census is the best description available to us, in the view of Professor John H. Rowe, of Berkeley, who has made a special study of the census categories as recorded by various chroniclers. Poma does not distinguish between the local, village ways of classifying age and sex and those used by the Cuzco administration. Indeed, his categories are phrased in the decimal terminology preferred by the Inca administration but, as Rowe indicates, they are not far from the categories into which human life was classified by the common language. The actual ages are approximations; the villagers—and, eventually the state—were more interested in the function and status of the individual than in precise chronology.

Apparently the census was conducted periodically throughout the country, with people lined up in rows or "lanes" according to sex, age, and function. A separate knot-string record, the quipu, was kept for each group—twenty in all—and to each group Poma devotes a page. Some details concern homely household routines, but Poma is also aware of the census as being a device of authority, providing information useful to the state and local lords in formulating economic and military policy.

Classification begins with able-bodied mature women and men, already married, to whom Poma assigns an arbitrary age of thirty-three. In the text he broadens this to a range of twenty-five to fifty—a period inaugurated by marriage and closed when one's energies were failing. His description of this longest and most productive age emphasizes the man's obligation to fight in the kingdom's wars and to work at construction and mining. He takes man's perennial agricultural work for granted in this section; but he also neglects the major obligation of the citizen as seen by the Inca state: work on the crown estates—the main source of revenue for a state that collected no tribute in cash or kind but only in service.

Marriage, the threshold of this main category, is implicit in Poma's writing but is not detailed. This is "the first law of the Indian women, married and widows... wed when they were thirty-three years old, until then they remained..."
virgins and maiden. These said women, and also the said men, married at the same age and until then they called them children.” It is very unlikely that marriage was delayed that long or that virginity was quite so prized. Under Inca rule, marriage was not just a personal turning point. It was an ingenious device of Inca statecraft to transform a once private action into a state matter; in fact, a taxation device. Only married men were required to provide their share of the state’s revenues, their wedded personal maturity and responsibility being accepted as evidence of new status by the administrators at Cuzco.

Neglecting the woman as homemaker and gardener, Poma reflects Inca values when he stresses that “the said women had as their job the weaving of cloth, ordinary and thin, and spun thread for the fine fabrics.” Just as every man farmed on the lands of the crown, so each woman—once married—owed a finished garment a year to the government. The fibers, cotton or wool, were provided from state warehouses, for the principle that no one owed the state anything from his own labor was applied quite consistently. In the second half of his letter Poma complains bitterly about European exactions of cloth, for which the Indians had to provide both labor and materials.

Poma’s drawings for the second of life’s lanes indicate an interesting contrast: whereas the fifty-year-old “woman and widow” continued at her weaving, the man in this age group was released from state military service. While continuing to farm, such a man’s state obligations now shifted to service for the koraka, the local lord. In a system such as the Inca, where every peasant household was essentially self-sufficient but was normally incorporated into a wider society that could not endure without the peasants’ contribution, the local lord, like the king above him, could neither maintain his staff nor display expected hospitality without calling for contributions from his subjects. In some cultures this contribution is in money, elsewhere in goods; but in the Inca realm these were unknown: the citizen—and in the local tribe, the member of the community—owed the authorities only some of his energy. How to apportion this energy between the various claimants was up to the local gentry. The koraka obviously found it easier to enforce his claim on those who were too young or too old for royal service.

What life expectancy was in the Andes before the European invasion we cannot say. Poma often mentions kings who lived past 100, and his decimal arrangement of the ages of man allows for a third lane, to cover the old and deaf, “30 and up to 150 years old ... who can only eat and sleep and, those whom can, weave mats and rope . . . and raise guinea pigs and . . . ducks.” Such failing energies did not bring isolation or destitution: “... they were much feared and honored . . . the whole village served them, these old men . . . and there was no need to have an old people’s asylum since their fields were harvested for them and their llamas herded . . . and thus they had no need for charity . . .” This system of permitting all hands, no matter how old or disabled, to own fields and pastures, worked for them by the community in a series of reciprocal services called ayni and minka, was in force also for the crippled or chronically ill, the mute, the hunchbacks, and the blind. In return, these persons rendered what services they could: “Those who had eyes were used to watch, those who had legs walked, those who had hands wove.”

Poma is alone among chroniclers in telling us that the handicapped formed a separate, fourth lane in the census. He even claims that they were matched in marriage with others similarly disabled “so they would give birth and multiply, so there would be more of them so that the earth would not remain sterile, alone.” This fear of the land’s being barren and empty of people is an anxiety we find again and again in the prayers recorded for the Inca period. In a country where less than 2 per cent of the soil is cultivable and where frost is a danger in many places every night of the year, the notion that the handicapped person should not mate is unlikely to be popular. Spinsters and bachelors are rare in peasant and kinship societies. It is interesting that even Poma reflects the tendency to attribute to the Cuzco regime of A.D. 1500 a concern for welfare of the disabled. In reality, an individual’s right to the good things in life, no matter what his physical
condition, was an age-old custom in Andean cultures. This confusion between pre-Incaic institutions and their attribution to the Incas is only now being unraveled.

The remaining six lanes, or strings of the quipu, deal with youths of both sexes before marriage. Since they were exempt from major duties to the state, their lives were centered in the village. The twelve pages that Poma devotes to young people are thus used to record unique information about peasant life in the time of the Incas. In the years before marriage, roughly between eighteen and twenty-five, men were watchmen in the fields, herders, and messengers. In time of war they accompanied the armies, carrying food and other loads. Though not considered full-fledged citizens until they married, these were obviously able-bodied young men; thus, Poma’s statements about them are startling: they were “virgins, who were ordered to eat raw corn, did not taste salt, nor chili peppers, no honey or vinegar, no sweets or meat, nor fattening things. [They] did not drink beer and [only] as a great gift did they give them a little hominy . . . nor did they know women in the entire kingdom.” Few of the foods prohibited are indigenously Andean, and every one mentioned was actually taboo to some people at particular times. But we have no corroborative data from other sources that such restraints were universal for the young.

Curiously enough, such food prohibitions are not mentioned on the page dealing with girls ready to marry, although in an earlier passage all women were thus restricted. The young women’s page deals primarily with the possibility of their being selected as aklya—the “chosen women”—“for the Sun and temples and the Moon and Morning Star and for the Inca and for the Gods . . . the said women served in everything ordered by the Inca and justice.” Since it is unlikely that the average woman observed all these food taboos routinely and since, in the case of men, Poma seems to generalize about practices that were actually occasional and ceremonial, one wonders if here again our author were not so much wrong as eager to attribute to all Andean women what was really the ritual and intermittent behavior of the aklya. His motivation for such distortion can be glimpsed in the closing lines of the page describing the young women: “everything bad, adultery and other mortal sins were brought with them by the said Christians.”

Adolescents helped their parents with herding, farming, weaving, and cooking. Their one obligation to the state has already been mentioned—catching brightly colored birds for their feathers, owed to the crown. This task seems to contradict the principle—no tribute in kind but only in energy—that was the heart of the government’s revenue system. Actually, in Inca thinking, wild, uncultivated resources such as game, lumber, and parrot feathers were crown monopoly since no local community could be said to own them. Ownership in Andean ideology—and this is likely to have been true even before the Inca—was related closely to cultivation and the subsistence it permitted.

At adolescence, the males also began to run errands for the local gentry, and such services made Guaman Poma reflect that “before there were Incas, each village had its own Inca and king, a lord to be served and the boys were a help [to them] and to the communities . . . Adolescent girls learned “to spin and weave delicate thing . . . they walked without elegance and barefoot and their clothing was short. They served their father and mother very much . . . and had much obedience and respect . . . They also picked flowers for dyes.” Domestic duties began even earlier for girls than for boys. It is interesting to contrast the five-year-old girl, fetching water, with the boy of the same age, who is spinning a top, although in the text accompanying the drawings they are not so far apart—both “helped in what they could” and both played.

Another noticeable contrast between picture and text is found in the animal headdress worn by the five- to nine-year-old boy, also seen in some of the agricultural drawings. There is no reference in the text to such pre-Europea
Ticking flowers for dyes is the task of 9-year-old girl and pinning thread occupies young woman "of marriageable age." Making cloth was of great concern to women of Andes, who, after marriage, owed the government a garment a year.

practises as the wearing of symbolic or ritual headdresses. The last two lanes enumerate children so small "they are for nothing [can do no work]. They should be served others and be played with by another child who should they do not fall, nor get burned, to watch him well, . . . is very right that his mother be freed [from other duties] for the children and if he is an orphan much more and if two be born from the same womb their mother and father should be freed for two years . . . a very old law in this kingdom . . . which the Incas ordered to be kept . . . there was no need for so much charity when they kept these orders." Another ordinance Poma liked was sat from the moment the child "left her mother's womb he was assigned lands and fields and they were worked by] her kindred . . . even if she had father and mother," his, he noted, also avoided the need for charity. Such desirable measures, Guaman Poma added ironically, "they have not had in Castile, nor will they have them."

The reason Poma thought Europeans would keep relying on charity instead of automatic welfare institutions like those he grew up with in the Andes deserves attention: "They [the Europeans] are roguish people, who from common men want to be lords, [coming] from poor lineage they want to be kings, to which they are not entitled by right of lineage or blood. . . .""Faced with the social and economic opportunities and aspirations that the invasion of the Andes made possible for invading Europeans, Poma retreats into what Dr. Raul Porras Barrenechea, a leading modern Peruvian historian, has called an aristocratic pose. Poma knew that many invaders were nobodies in the feudal world they came from; that
they put risk and opportunity ahead of established rank and privilege; that he, on the contrary, was the grandson of an Inca viceroy come to little. But one can say that Poma was aware of the systemic differences between the European and Andean societies; in the latter there was no need for charity because the welfare features were built in. No one was poor because no one could be deprived of what today we call capital goods: lands, herds, and access to the reciprocal services of others, particularly one's kin-folk. This was no longer true of Europe.

N to place for deviation from the ideal norm exists in Poma's system. The Andean world was well organized, according to him, and this was adequate to deter wrongdoing: “this justice and law they had in the whole kingdom and they were punished by the governors, toqtoroc, and judges, michoc ... and ... there were no murderers, nor lawsuits, nor lies, nor petitions, no court officials, nor thieves. ...” This idyllic picture need not detain us, since we have already seen among the agricultural drawings the thief stealing the new corn. We know from other sources that local headmen had permanent court functions and that litigation between communities over water and pasture rights was common. But Poma himself gives us information elsewhere, where he is eager to show the civilized nature of the Inca world, that gives a truer story: “punishment of lazy ones and dirty and pigs who own nothing clean, with dirty hair and faces and smelly mouths ... and clothing, they were punished with one hundred lashes with a sling. ...”

Dr. Sally Moore, a lawyer and anthropologist, made a study of Inca law recently—a difficult task, indeed, since there was no Inca writing and thus no record of court proceedings or legislation. It is particularly difficult to separate the various local ethnic norms from the Inca decrees dictated in Cuzco, but apparently in both systems punishment was direct and corporal: whipping, torture, Stoning, and the death penalty prevailed. In contrast, there we few fines and virtually no jails. There must also be existed many less formal mechanisms of social control enforce the cultural ideal. Most of these have been lost.

Of all misdeeds and deviations, those of a sexual nature obsessed Poma. Many of the pages and illustrations in the second half of his manuscript, which deals with color images, return to the disintegration of Andean standards under the blows of European occupation. Rape and seduction of Andean women by the invaders were not only a major social problem in the sixteenth century but also, inevitably, a personal concern. Recall that one of Poma’s brothers was the priest who educated him, had a European father. the story behind this is never explained in Poma’s document. In contrast to such contemporary reality, the Inca assumes in Poma’s eyes orderly and virtuous procreation. Not only were men and women chaste until marriage—-we have seen, but Poma has also classified all deviations from such chastity as adultery and made of it a real crime and a sin. “If the man forces the woman, he is sentenced to death and she to two hundred lashes with a nail and exile to the house of the inka, the chosen woman, where she will serve all her life ... if the woman forces a man, she is sentenced to death and he to the lashes of exile to the jungle, to the Chuncho Indians so he will never appear again and if they both agreed they both will not be buried and they will be eaten by vultures and foxes and their bones will lie about on the ground. There is obviously much fantasy in this vision of intervention into marital matters, although it is not
THREE MEDICINE MEN demonstrate their specialties: talking to the devil while dreaming, at top; summoning the devil through fire, at center; and sucking illness from patient.

likely that there were community measures that went beyond revenge by the injured party in cases of adultery. Another of the areas of Andean culture where Poma's formation is both exasperatingly patchy and frequently revealing is that of religion. We still know very little about peasant belief and practices, since most chroniclers dealt only with the state church and its sumptuous ceremonies in Cuzco. Only toward the end of the sixteenth century is there a change of emphasis; we begin to hear of rural cults, of village folk resisting relocation away from local shrines, of differences in burial customs from province to province. At this time the European clergy, embezzled in conclave in Lima, complained that heathen practices endured everywhere although the Indians had been converted and baptized for fifty years. Much as in Acapant, where Bishop Diego de Launda (who burned the Maya scrolls) is our chief source on Maya culture, so in Peru the persecutors of Andean religions have often left tailed, valuable accounts of which they destroyed.

WE gather from other writers that much of Andean peasant religion centered on agricultural ritual, whereas the state church was primarily concerned with size, local shrines and deities shared their parishioners'idity about the staple tuber crops. Many activities—such as herding llamas, clearing irrigation ditches, nuturing avocado pears, or gathering coca leaves—were defined by the Andes as religious endeavors, although the realistic efforts that accompanied them to ensure a food supply were never neglected. Sacrifices and libations were integral part of the rites, particularly when catastrophes threatened the world of man. Foodstuffs, cloth, llamas, and, in great emergencies, even humans could be offered in propitiation. At moments of great crisis, black llamas

MURDER BY WITCHCRAFT brought death penalty to witch's whole family except nursing infants, who had not learned "trade." An example of author's calligraphy is seen below.

POR LA CIERACON MUY MUY

ACABO
Dr. MURRA, Professor of Anthropology at Vassar College, has made intensive studies of Andean life. The second part of his article about Poma's Peru will appear in October.

and black dogs were beaten in order to attract the attention of the deity by means of their cries.

The Europeans destroyed the Inca church very soon after 1532 and also persecuted the local cults. Yet, like Andean agriculture, Andean religion has managed to endure until today, and many of the rituals and spells Poma describes can still be studied in the Andes. Despite his pro-European bias in religious matters, Poma had good knowledge of traditional beliefs, possibly because of his idol-burning activities. Frequently he gives unique data about the shamans, all of whom he calls witches, but whose functions and talents he differentiates soundly. There were, for example, "witches who slept and between dreams talk to the devils and tell them . . . all that is happening and all they want and ask for. There are dream witches and when they wake they sacrifice to and adore the devils. These are witches of subtle secrets, . . ."

Other witches spoke "with devils and such and say that they suck out illness from the body and they take out coins or a stone or sticks and worms or a frog or a kernel of corn from the body, . . ." Still other witches, says Poma, "take a toad, remove the poison from a snake and they say they talk with them and poison people . . . They take the toad and sew up its mouth and eyes with thorns and they tie up the toad's hands and feet and they bury it in a place where the enemy or the ill-wisher is likely to sit down so that he will suffer and die there, like the toad who does not die but it suffers . . ."

ELSEWHERE in his letter Poma tells us how murder through witchcraft was punished: "those who give poisonous draughts and venoms that kill the Indians . . . who keep toads and birds to kill people . . . these Indians were killed . . . with all their caste and kindred and their sons and grandsons, escaping only the children who were still suckled since they did not know the trade and thus they escaped death. These [dead] were not buried but left to be eaten by condors and vultures and foxes in the field. . . ." The destruction of a man's whole lineage is reported by other sources in cases of rebellion and treason. Always in favor of orderliness, Poma may again be guilty, here, of extending the range of punishable behavior to meet potential European criticism.

Although he lived in various parts of Peru in his youth and visited other areas while in the service of the clergy, Poma shows relatively little knowledge of or interest in the variety of cultures and customs prevalent in the Andes. He was narrowly patriotic: the people of his own region, who "although they are Indians small in body, are brave in warfare because they eat maize and drink maize beer which gives strength . . . and puts them ahead in the kingdom . . ." are contrasted to the Kolla, dwellers in the high Southern Andes, who " . . . were Indians of very little strength and courage . . . fat, sucy and good for little since they eat potatoes and drink potato beer."

Although such stereotyped notions about the various pre-Inca ethnic groups are numerous in his work, Poma shows more sensitivity to real differences when dealing with death. He devoted nine pages to mortuary customs, and one senses that here was a topic about which he was well informed. The Kolla people of the South "dressed [the corpse] and mourned him on the first day and on the fifth day they bury him sitting, with much clothing and pottery. If he was a poor Indian he is brought much food by his father and mother and the relatives and brothers and friends send him food or beer . . . and with this they bury the dead on the fifth day . . . and on the tenth day they mourn him again and send as many gifts and then they burn him and when the flame of the fire crackles they say he is received by the dead ones and they go directly to Acaraypampa, the plain of the dead . . . and they say that there is much festivity there and conversation among the dead male and the women . . . and so they bury them with their food and drink and always they take care to send them to eat and to drink . . ."

In his own area, farther north, Poma reports that "on the fifth night after death they held a wake and the fasted not eating salt and other dainties. Then they kill a llama and they ate it raw or cooked but without salt or chili peppers and they made a dish with potatoes and raw blood and they feed the dead one . . . and they weep and sing their songs and dances . . . and they shout and er and he who cries most, that one drinks more and get more meat and the woman who sings and has a good voice for weeping she receives a leg of llama . . . and the dead one is washed and they dress him in all his clothes and feathers and jewels . . . and they put him on a litter and they go in procession . . . They sing and follow him jumping and each lineage goes weeping and they bury him. . . . The good widow makes these ceremonies last two years and on each anniversary [there is] much preaching from the old Indians . . ."

One wonders why Poma displayed so much interest in death, to the exclusion of other religious and life cycle activities. Beyond his personal anxieties about death an his unpreparedness for it according to local standards—something we cannot plumb at this distance—one explanation could be his share in the campaign to "root out idolatry" that centered on the visible rites surviving five or six decades after the European invasion. After 1572, when Viceroy de Toledo began to resettle people forcibly throughout the Andes to facilitate tax-collecting and control, it became obvious that villagers were greatly a tached to their cemeteries and it took a major effort to keep them away from their traditional settlements.

Poma's picture of the Andean village is obviously incomplete and often contradictory. A man of truly transitional times, Poma found himself condemning on some pages the very things he had praised elsewhere. But his native testimony remains of enormous value to those interested in how Andean Indians reacted to the invasion of their country and to the destruction of their culture. In the history of European colonization the world owes there are few documents from any native's pen so dailed, so genuine, and so revealing. Guaman Poma's lost chronicle manages to contribute at one and the same time to Andean anthropology, to the history of modern Peru, and to our understanding of the life of colonized man.

(Festival of the Dead was in November, the month of the dead. Skeletons were taken from vault, given food, dressed in new clothes, and taken from house to house on a little
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la fiesta de los defuntos
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Caterpillar of polyphemus moth is clear green and has raised, silvery-white lines on side. Larva feeds on oak, birch, and other trees, finally spins a cocoon that contains a long and unbroken thread of silk.

THE COLORFUL POLYPHEMUS multihued moth begins its life as a bright green caterpillar

According to Greek myth, Polyphemus was a one-eyed giant who imprisoned and was subsequently blinded by Odysseus. His namesake is a sober giant, formally known as _athecus polyphemus_—a silkworm moth of the family Saturniidae, which includes the largest of the Lepidoptera. The polyphemus moth is a New World species that ranges through the United States and into Mexico. The cordon-bodied caterpillar is a magnificent clear green, sometimes tinted with a bluish cast. After a series of molts, the larva leaves the food plant and finds a place to pupate. The dense cocoon it spins is attached to a twig or, on occasion, rolled up neatly in a leaf. When the cocoon is completed, the encased caterpillar releases a fluid that soaks through the silk and hardens, "winterizing" the structure.

In early spring the spectacular adult moths struggle free of the cocoon, and spend the rest of their brief life mating and laying eggs. As an adult, the polyphemus does not eat. During its larval life it has stored fat, which continues to nourish it during the pupation period and while it makes its nuptial flights at twilight.

So marginal is the adult life of this moth that it is not unusual for the female to fall dead at the base of the very plant on which, seconds before, she had deposited the last of her eggs.
After emerging from cocoon in late spring, the adult moth begins expansion of its wings. As the veins are pumped full, the wings unroll and spread, as shown, from left. The process requires several hours.

Toward the end of the expansion period, wings become prominent, finally gain full size, right. Spread of wings may be as great as six inches. Eyelike spots on the hind wings may serve to confuse enemies.
Peering over "cliff," kitten resists leaving board that spans glass in laboratory test of depth perception. One of two visual cues is clearly demonstrated here: phenomenon of size and spacing of patterns that decrease with distance.
ONLY ONE DAY OLD, kid already exhibits its capacity for depth perception as it huddles by side of test frame to avoid the “chasm” beneath. Despite the fact that kid stands on solid glass, its “sense of danger” depends more on visual cues.

Crossing Visual Cliffs

Depth perception in animals is tested by control of optical cues

By ELEANOR J. GIBSON and RICHARD D. WALK

HUMAN INFANTS at the creeping and toddling stage are notoriously prone to falls from more or less high places. They must be kept from going over the brink by the panels on their cribs, gate on stairways, and the vigilance of adults. But as their muscular co-ordination matures, they begin to avoid such accidents on their own. Now, common sense might suggest that a child learns to recognize falling-off places by experience—that is, by falling and hurting himself. But is experience really the factor? Or is the ability to perceive and avoid a brink part of the child’s original endowment?

At Cornell University, we have been investigating these problems by means of a simple experimental setup that we call a “visual cliff.” The cliff is a simulated one and hence makes it possible not only to control the optical and other stimuli (auditory and tactual, for instance) but also to test the experimental subjects. It consists of a board slid across a large sheet of heavy glass that is supported a foot or more above the floor. On one side of the board, a sheet of patterned material is placed flush against the undersurface of the glass, giving the glass the appearance of solidity as well as the substance. On the other side, a sheet of the same material is laid upon the floor: this side of the board thus becomes the visual cliff.

We tested thirty-six infants, ranging in age from six months to fourteen months, on the visual cliff. Each child was placed upon the center board, and his mother called him to her from the “cliff” side and the “shallow” side successively. Twenty-seven infants moved off the board. They all crawled out on the shallow side at least once, while only three crept off the “brink” onto the glass over the cliff. Many of the infants crawled away from the mother when she called to them from the cliff side; others cried when she stood there, because they could not come to her without crossing an apparent chasm. The experiment thus demonstrated that most human infants can dis-
criminate depth as soon as they can crawl. It also gave clear evidence of their dependence on vision; often, they would peer down through the glass on the deep side and then back away. Others patted the glass with their hands, yet—despite this tactual assurance refused to cross.

This experiment does not prove that the human infant's perception and avoidance of the cliff are innate. Such an interpretation is supported, however, by the experiments with non-human infants. On our visual cliff, we have also observed the behavior of chicks, turtles, rats, lambs, pigs, and dogs—as well as the kittens and kids pictured here. These animals showed various reactions, each of which proved to be characteristic of their species. In each case, the reaction was plainly related to the role of vision in the survival of the species, and the various patterns of behavior indicate vision's role in evolution.

Kids and lambs can be tested on the visual cliff as soon as they can stand, and their response is predictable: no kid or lamb ever stepped onto the glass of the cliff side, even at one day of age. When one of these animals was put down upon the glass over the cliff, it displayed characteristic, stereotyped behavior: it would refuse to put its feet down and would back up into a posture of defense, its front legs rigid and its hind legs limp. If pushed forward across the glass until its head and field of vision crossed the edge of the surrounding solid surface, the animal would then relax and spring forward upon this surface.

At the Cornell Behavior Farm, a group of experimenters has carried these experiments with kids and goats a step further. They fixed the patterned material to a sheet of plywood and were thus able to adjust the "depth" of the deep side. With the pattern held immediately beneath the glass, the animal would move about the glass freely. With the optical floor dropped more than a foot below the glass, the animal would immediately freeze. Despite repeated experience of the tactual solidity of the glass, the animals never learned to function without optical support. Their sense of security or danger continued to depend upon the visual cues that give them their perception of depth.

Cats are nocturnal animals and, like rats, are sensitive to tactual cues from their whiskers. But whereas a rat is apt to rely primarily on its sense of smell and tactual cues the cat, as a predator, also relies strongly on its sight. Kittens proved to have excellent depth-discrimination. A four weeks—about the earliest age that a kitten can move about with any facility—they invariably chose the shallow side of the cliff. When put down on the glass over the deep

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Dr. Gibson, of Cornell University, and Dr. Walk, of George Washington University, collaborated on the depth perception experiments described here while at Cornell.
Kid relaxes noticeably as soon as its field of vision has crossed edge of board.

Safe on the crossboard, kid peers over chasm. Action of even one-day-old kid is predictable; animal seldom steps onto glass over deep side of its own accord.

ide, they either froze or circled aimlessly backward until they reached the solid assurance of the center board.

All our observations were in agreement with what is known about the life history and ecological niche of each of the animals tested. The survival of a species requires that its individuals develop discrimination of depth by the time they take up independent locomotion, whether at one day (the chick and the goat), three to four weeks (the rat and the cat), or six to ten months (the human infant). That such a vital capacity does not depend on learning by possibly fatal accidents in the lives of individuals is, of course, entirely consistent with evolutionary theory.

We set out next to determine which of two visual cues plays the decisive role in depth perception; for to an eye above the center board, the optical pattern on the two sides differs in at least two important respects. On the deep side, distance decreases the size and spacing of the pattern elements projected on the retina. "Motion parallax," on the other hand, causes the pattern elements on the shallow side to move more rapidly across the field of vision when the animal moves its position on the board or moves its head, just as nearby objects seen from a moving car appear to pass by more quickly than distant ones.

To eliminate the potential distance cue provided by pattern density, we increased the size and spacing of the pattern elements on the deep side in proportion to its distance from the eye. With only the cue of motion parallax to guide them, adult rats still preferred the shallow side, though not so strongly as in the standard experiment. Infant rats chose the shallow side nearly 100 per cent of the time under both conditions, as did day-old chicks. Evidently, both species can discriminate depth by differential motion alone, with no aid from texture density and probably little help from other cues. The perception of distance by binocular parallax, which plays an important part in human behavior, would not seem to have a significant role, for example, in depth perception by chicks and rats.

To eliminate the cue of motion parallax, we placed the patterned material directly against the glass on either side of the board but used smaller and more densely spaced pattern elements on the cliff side. Both young and adult rats preferred the side with the larger pattern, which evidently "signified" a nearer surface, but it may be that learning played a part in the choices shown by the rats.

From our first few years of work with the visual cliff, then, we are ready to venture the rather broad conclusion that a seeing animal will be able to discriminate depth by the time its locomotion is adequate, even when locomotion begins at birth. But many experiments remain to be done, especially on the role of different cues and on the effect on the animals of different kinds of early visual experience.
THAT ELEGANTLY FORMED BIRD, the tern, is not likely to have been overlooked by summer visitors to Cape Cod or to many other areas along our Atlantic coast line. As it hovers over the water and then dives for fish, a tern, with its sharp contours and arrow-like descents, is a pleasure to watch. These birds are an animate revelation of keenness and precision. They pinpoint the summer waters with flashes of spray, from which they rise with silver prey in their bills. They seldom miss in their quest for food.

Is there any action more full of grace than what some observers have called the "aerial glide" of a pair of terns? This spectacle may occur, among mated adult birds, at any time from the beginning of the breeding season until after the young are flying on their own. One August not long ago, I watched such a pair come in over the shore after they had been beating low along the wind-silvered waters of Cape Cod Bay. Suddenly, the pair mounted high up together, then raced in overhead. It was a sort of fast, lilting run. They came very close together, in synchronized proximity, like a pair of champion skaters. Then this lovely chase looped back and swung lower down, shifted on a slanting keel, and passed over the water once more.

Being a bird not only smaller but less in evidence than the omnipresent herring gull—which dwells on our shores, roosts on our houses, and scavenges in greatly increasing numbers at our town dumps—the tern seems a shimmering visitor, a bright surprise. Terns seem nervous and excitable by nature, and they are often unpredictable in their social movements. They are evidently sensitive to environmental change and to fluctuations in food supply; colonies have been known to desert nesting grounds in mid-season.

In the general area of Cape Cod there are two principal nesting places: Tern Island, at Chatham; and Plymouth, on Cape Cod Bay. During the season—the birds arrive about the end of April—both terneries have populations that number in the thousands. There are, in addition, a few small islands off the Cape and a few comparatively isolated areas where smaller aggregations often nest successfully, although terns are sociable birds and
reed best in large numbers. Beginning in August with the Arctic tern, which is the earliest to migrate, the birds start to leave these nesting sites, sound south in groups or small companies. They spend the winter anywhere from Florida southward almost to the edge of the Antarctic ice.

It was about the middle of August when I first saw four or five hundred common terns appear in an area where had not been aware of them before. It was high tide and the birds flocked along one bank of Paine's Creek, a tidal estuary that flows out to Cape Cod Bay from the township of Brewster. The stream, cutting through grassed dunes, separated the terns from town beach and landing. During ebb tides, at this time of the year, its brackish waters carry out large numbers of alewife fry, “inland herring” that have hatched in Brewster's freshwater ponds. Since there is also an abundance of sand eels in the area, the terns had a good fishing ground.

From what nesting colony or colonies the birds had come was impossible to tell. In any case, Paine's Creek represented a way station on one leg of their migratory journey south, and the first such stop for birds that had hatched in late spring or early summer, as well as for the older birds.

Most terns reach flying age within a month of birth, but their parents go on feeding them for some time, even at the outset of the southward migration. The young birds are slow to mature and do not breed until they are about three years old. I could see by their plumage and their behavior that many of the birds at Paine's Creek were immature. The crowns on the heads of the adults are jet black, while the heads of the young are gray.

Some of the young were making inexperienced flights over the water. They plunged in and sprang out of the water in an almost kittenish, hit-or-miss way, while the adults were hovering and diving with precision. Most of the immature birds, however, stood dependently along the beach or on shoals at the inlet's mouth, crying and begging their parents for food.

Terns are intensely active and brilliant in performance. Although comparatively small birds, they are made
balanced natural art. Other adults swung in with sand eels or alewives in their bills, and hovered, or circled back, avoiding rivals. Then they would drop down, next to a twittering, gap-beaked juvenile, sometimes giving it the whole fish, and sometimes holding on to half of it and flying away—an action that had the effect of teasing the young bird to follow after. In this way the young, some still crouched as if they were nestlings, became increasingly adept at flying up, chasing, diving, and dodging, at breasting the air, and beating their wings for all the long voyages their lives would hold.

In a few weeks, most of these birds would suddenly flock away, in the next move of their migration. In the meantime, they practiced the lessons of growth—training in the insistent, excitable ways of a tern, a prelude to life in air over half the earth.

During the following weeks, or through September, I noticed that the plumage of the juvenile terns began to show a more definite contrast. Their heads were getting darker for journeys that take them thousands of miles, and their long, angled wings beat deep, low, and strong. I watched them, this shining August day, as they flashed with the brightness of gold circles of water around sharp grasses along a shore. They were all swinging, darting, winnowing the air. "Kierr! Kierr!" they cried; and their white shuttlecocks of tails would spread and settle as they turned against the wind.

Two juveniles were waiting on a shoal, constantly calling in a high-pitched tremolo, intensified whenever the parent bird swept by above them. As I watched, the trim, expert adult flew over, then swung back down the shore and circled round, finally coming in to land between the pair. The adult had no food, but stood between its young for a minute or less and then began to move away, while they crouched and strutted after it in what, to human eyes, was an almost elderly way, crying in protest. The parent signaled departure with a slight lift of its wings and, in a few seconds, flew away. The thwarted young ones took to the air behind the parent.

In the terns' behavior that August day, I saw the play of learning, and the many repetitions that precede a

large fish is being freely offered by a parent tern to its twittering, gaping young, above. Sometimes adult gives an entire fish; other times, only a part.

Preparatory to flying off, parent tern moves away from between its two young, above. Deprived of food and crying
They had also become more practiced in flight. Many young were still being fed by adults—almost continuously during ebb-tide hours, when food was abundant in shallow waters offshore. The impression that less food was being proffered by the parent birds, though they were still very much on the job. When they brought a fish, their large dependents, whose passivity almost looked like a consequence of being overly stuffed, would gulp it down and wait for more. Other young birds were flying now: chasing after their parents, beseeching attention, and often fishing for themselves.

Little by little the young were progressing toward the perfected action of mature birds. They were becoming more aggressive, fighting for space over a crowded channel, or protecting their catch. The adults, whose success in fishing they were beginning to approximate, would hover over the water, beaks pointing down, then dive suddenly, wings partly folded back. They would hit the water like small stones, then come up again and fly away fast—chased, if they had a fish in their bills, by other birds that cried "Karr! Karr!" with a slightly growling note. I became aware of a general coordination in everything they did. Their circling, diving, hovering, or racing downwind, were all parts of a common proficiency of motion that fitted the great environment of air and sea. Growth was rhythmic practice.

Many aspects of tern behavior have been studied exhaustively by such authorities as Niko Tinbergen, Ralph Palmer, the late Oliver Austin, and his son, Oliver Austin, Jr. From their descriptions, I had accumulated the impression that terns were almost constantly involved in a ritualistic performance. There is, for example, the "fish flight," a term that in its strict sense seems to apply to the behavior of birds during the precourtship period. This action involves emotional display between pairs of birds, as distinct from a tern's food-collecting habits in general. In detail, it includes differences in calls, in the relative positions of birds during flight, and in the way they carry fish. A fish in the bill represents not only the fulfillment of a need for food; it may also be an offering, a display, and perhaps the instrument for a mutual awareness,
Mr. Hay frequently contributes to this magazine. His article appeared in somewhat different form in his latest book, *Nature's Year*, which was published by Doubleday in May.

even before sex recognition occurs. But if this fish flight can be linked to behavior at a particular stage in the tern's life, the birds also show similar reactions before and after that stage. Palmer points out (in *A Behavioral Study of the Common Tern*) that, although no fish is involved during the aerial glide, this graceful maneuver still represents a continuation of the fish flight phase. Also, mated pairs go on offering fish—or begging—they fly by one another, so that feeding is used, in Palmer's words, "as means of maintaining a bond." As of course the fish, proffered or withheld, is the basis of all the training that the young experience during the course of growth. The process of begging and receiving, or offering for the purpose of recognition, continues in many forms throughout a tern's life. The birds appear to be pursuing a formality. Even their flights show the grace in action of a whole society.

At low tide, the terns I watched those months would begin to flock along the wide sand flats, prodding and bathing in the tide pools. Occasionally one would lift its wings into the wind while it preened, receiving the wash of air. Some flew to the creek inlet and drank of the brackish water. As the September days went by, the whole tern community seemed to gather more and more together. At times, all of them would take to the air, as if in alarm, although no cause was visible. Or I would see them spinning like a flock of sandpipers-white clouds dancing with dizzy perfection over some fishweirs in the distance. Perhaps these actions could be called communal practice for the next step in the southward journey. In the rhythms, the terns were self-sustaining and self-protective, like schools of fish. But, at the same time, the birds were living under the laws of the wild.

One day in early October, when I went down to the shore again, most of the had flown away. One lesson was over.

*Migrating terns, including young as well as mature, gather on coast, rise attracted there by offshore fishweirs.*
Concave tongue of vampire fits over a V-shaped notch in lower lip. This forms a tube through which animal sucks blood—in this case from dish in a laboratory.

THE MEXICAN BLOOD DRINKERS

Vampire bats display special adaptation

By Bernardo Villa

Among the many species and subspecies of bats known from the Americas, 140 are now known from Mexico. Among them are vampires, or blood-drinking bats, which have proved to be the main reservoirs and vectors of the fearsome rabies virus.

Vampires' biology and feeding habits have interested man since ancient times. For instance, the Cakchiquels, a Mayan tribe, believed the Camazotz—the vampire—was a god who killed victims with his sharp, pointed teeth.

Recent observations in field and laboratory have shown that their bite may indeed be fatal, as it opens the way for rabies infection. But, contrary to the beliefs of naturalists of the eighteenth century, the wound is not made by the nasal leaf (which, in fact, is not found in vampires), nor do the bats fan their intended victims to sleep before allegedly thrusting the tongue into a blood vessel and drinking.

We now know that the mouth and tongue are specialized to imbibe blood in a manner without parallel among other mammals—or, indeed, among other vertebrates. The V-shaped notch in the lower lip is opposed to the concave lower side of the tongue. This forms a tube, through which the bat, after first making the wound with its sharp upper incisors, sucks blood. Thus, there is no lapping, the sound of which might awaken the victim. To further reduce any sensations on the part of its prey, the bat rests lightly on its wing thumbs and small foot pads.

The photographs showing this manner of feeding were taken in the zoology laboratory of the Instituto de Biología at the University of Mexico.

Dr. Villa, who took the photographs for his text, heads the Department of Mammalogy at the University of Mexico.
After drinking 20 or 25 cc. of blood, bat begins withdrawal to roosting place.

On wing thumbs and feet, a bat can cover ground with remarkable speed.

While backing up wall of its cage, bat pauses to assume typical defense pose.

Two vampires hang characteristically from roost in corner of laboratory cage.

is, like other vampires—and contrary to legend—confined to New World alone.
I was prowling peacefully along a rocky shore, collecting mussels for dinner, when I heard a splash. Just beyond the outer line of rocks I saw a column of water vapor shoot into the air like the spout of a whale, but in miniature. A glistening black object broke the surface. It floated for a minute and then, instead of diving, it started moving slowly toward shore. As it approached, I could see that it was about the size of a periscope and had a bright, fluorescent yellow stripe along the water line. As it pulled itself up on the beach, the eyes came into sight. They were about four inches in diameter and were located on the ventral surface, one behind the other! The creature got up on its hind flippers and waddled awkwardly toward me. It was my friend, Martin, in his new skiving suit. The upper eye was his face mask, the lower one was the port of a camera housing strapped to his chest.

"I got some wonderful pictures," said Martin, "...if they come out."

How that phrase took me back in memory! It had been years since I’d wondered whether a picture would "come out." But when I started taking underwater pictures myself, I found that no thought could be more appropriate.

Underwater photography was much in vogue about five years ago. Photographers, apparently suffering a mass attack of Cousteau’s "rapture of the deep," trooped down to the sea like lemmings. Everything was photographed under water—telephones, automobiles, models in dry-suits, pretty girls in bathing suits, pretty girls without bathing suits, housewives pretending to make toast, and children pretending to drink soda pop. Most of these pictures were not remarkably good, but it was remarkable that they could be taken at all. They attracted attention, and that was what they were supposed to do. By now everyone has seen pictures made under water, the hucksters have moved on to other gimmicks, and underwater photographers can return to photographing things that really belong to the undersea world.

Stepping into the sea with mask or goggles is much like entering the world behind the looking glass. The silvery barrier that seems so thin and yet so formidable opens only enough to let one pass, and closes immediately. The undersea world is breathtaking, and before long you want to take pictures of it. Then comes the rude discovery that entering that strange, submarine world means retreating to the dawn of photography.

We have got used to the fact that, in air, the camera can photograph anything the eye can see—and often more. It can cut through fog. It can make a fly in the eye, and it can bring distant subjects closer. Almost anything you want the camera to do can be done—if you have the money for accessories. Almost any technical information you may want is published in handbooks.

That other world below the surface, everything is different. The experts still hand-build much of their own equipment. (When did you last build a camera?) There are no reliable tables of exposure, filter factors, development times, or any of the other things we have come to take for granted. The few tables that have been published hold good only for the waters where they were derived, and the only sound recommendation is to make a test and see if it comes out. If it does, you still won’t know much, because underwater optical conditions change from day to day, and even from hour to hour. And, under water, the camera can see much less than the eye. This is partly because we have two eyes and can therefore concentrate on things at one particular distance, ignoring what is in front of and behind that point. But a larger factor is the marvelous ability of the mind to perceive shapes and organize visual clues. The eye can detect minute differences in color or texture. The perception of motion helps, too. Many forms of marine life are so camouflaged as to be invisible until they move. Needless to say, they are completely invisible in a still photograph. The only way to photograph them is against a different background—one that they don’t match. A ray lying on the bottom is virtually impossible to see in a photograph, but a ray swimming can be seen from the side against a background of water, or from below against the surface.

When we pick up rocks or sea shells at the shore and take them home, they seem somehow to lose their luster. The same is true of the wonders we try to capture on film. I am afraid the truth is that just as the eye can see under water only a fraction of what it can see on land, so the camera under water can record no more than a fraction of what the eye can see. Water clear enough for good underwater photography is found in only a few places, and then only at certain times. The water is very clear in the Bahamas and there are enormous stretches of white sandy bottom at twenty feet or less that reflect light and give a beautifully rounded illumination. Marine life there, however, is not as abundant as in waters that offer more food and more concealment. When the movie 20,000 Leagues Under the Sea was filmed there, whole undersea gardens were brought in and set up by prop men. Even so, the film company sat for several weeks waiting for good weather.

In the Florida Keys there is more to photograph and the water can be very clear at times. May and June are the best months. But coral shores undergo a continual "snowfall" of minute particles of eroded coral. The slightest wind stirs up the bottom enough to prohibit picture taking, and a severe storm will cover the undersea landscape with two or three inches of silt. One day in five may be a good day for underwater photography.

The best conditions are found in the eastern Mediterranean, where the water is as clear as laboratory distilled water, and in certain large springs where the water is free of organic or mineral sediment. (Many of the "gimmick" pictures of the early underwater period were taken in these springs.) They generally do not support much aquatic life. Other waters vary from fair to impossible.

Have you ever wondered why we do not see any over-all pictures of the sunken Spanish galleons that writers are so fond of describing? The answer, I suspect, is that no camera can see from one end of such a ship to the other. It may almost be taken as a fundamental law that "there are no long shots under water."

These discouraging facts are forced on us by the nature of the medium. Water is much less transparent than air, and natural bodies of water (as distinct from swimming pools or aquariums, where the water is filtered) contain quantities of minute particles in suspension. Some of these are plants, some are animals, and some are bits of sand, mud, or coral, but they all impede the passage of light. Some of the particles absorb light (actually they convert its energy into heat) and others reflect or "scatter" it. Scattering is more of a problem for the photographer than absorption. It produces the same effect that heavy dust clouds or thick fog do in the air. There
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To overcome photographic flatness, a shirly energetic developer should be used or black and white films. I have had best results with UFP. Developing times would be 10 to 20 per cent longer than usual. Although it seems a good idea to use a slow film because such films have higher inherent contrast than fast ones, it is probably better, in actual practice, to use a medium-fast film in shallow water and a fast film in deep water, so that the lens aperture can be kept small to overcome difficulties in focusing.

It is not really practicable to increase contrast in color. but fortunately this is usually necessary. Kodachrome is a better contrasty film, but it is not a good place under water because it emphasizes blue and green, which need to be duced. Ektachrome (particularly the High Speed emulsion) and Anscochrome will give better color rendering, if their higher speed will allow use of smaller aperture. Kodalchrome 11 is so new that I have not yet evaluated its underwater performance.

There are other tricks for overcoming the other kind of flatness—lack of apparent depth—although, of course, these do not really restore what low visibility takes away. Framing is the most effective technique. This means having a 1ark object in the near foreground at the edge of the picture. Shooting through a hole in a coral or between two rocks is a good way to achieve this effect. The best is to shoot from inside an underwater cave, but since caves are often frequented by moray eels and other unfriendly creatures, I would hesitate to advise any readers to back into them.

Another useful technique for simulating depth is back-lighting. This means simply having the light come from behind the subject. It is frequently impossible, of course, but it is usually worth trying. Shooting up at an angle toward the surface is one way; photographing fish in the shadow of your boat is another. Framing and back-lighting are useful above water, too, especially when the air is dusty or foggy. They have been used in many of the best pictures of rodeos, marine mists, and London streets.

Increased exposure will not help penetrate underwater mark because the film will record the scattered light instead of the image we want to see. In fact, a minimal exposure and extended development are best. Filters will improve the situation. The suspended particles scatter more blue and green than other colors, so a yellow or orange filter will reduce the intensity of the scattered light, somewhat and will allow more of the image to show. But no filter will eliminate the particles themselves.

When shooting in color, filters can be used only sparingly—just enough to restore the balance of the different colors that make up "white" light. The filters used for color, therefore, will not help much in penetrating underwater haze.

Exactly the same limitations apply to aerial photography through fog; the heavy filters that give maximum penetration in black and white cannot be used for color, because they would eliminate most of the color from the picture.) Color does help, however, by making the subject stand out and by increasing the feeling of depth. For this reason color pictures are often better than black and white photographs of the same subjects, but the shooting conditions must be better for color to succeed at all.

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Underwater housings come in a variety of futurist shapes and materials. They look fancy, but compare with modern cameras, they are crude. The Rolleimarin housing for the Rolleiflex-designed by Hans Hass—an expensive—is one of the few that can really be operated conveniently under water.
soft plastic bag with a circular glass port at one end. All the controls on the camera can be operated through the plastic while submerged, an advantage that cannot be claimed by many housings costing well over $100. The heavier, cast-metal housings are watertight at greater depths, but this is a dubious advantage because there is not enough light to take pictures at those depths anyway, unless artificial light is used. A housing that is airtight to 250 feet and has no flash connections is a waste of money. With any of these housings, the shutter speed and aperture can be changed only by opening the housing. This means that the photographer has to make a preliminary descent to take a meter reading—sealed fruit jars make a good meter housing—then surface to set the camera, dive again to take the picture.

Even less convenient, most housings I have seen for $30 or less have no mechanism for focusing the camera and no way of setting the lens when it is in focus. They thus uniform an expensive camera into a dull object of a box camera. True, the lens is faster, but if it can't be focused, has to be stepped down for greater depth of field, so the lens speed is wasted. It is more sensible to buy a box camera. There is an underwater box camera on the market for $15. It is made entirely of plastic and the camera forms its own housing. The shutter speed, focus, and aperture are fixed, but the sensitivity can be controlled to some extent by having different types of film. This camera will do almost everything that an expensive one will do and it has one great advantage—if the case leaks, nothing will ruined but one roll of film.

Another radical, but highly practical, suggestion is not to take the camera under water at all but to shoot instead rough something like a glass-bottomed boat. A sophisticated version of this simple instrument can be built with a rectangular glass bottom the same shape as the negative. A mount can be installed to hold the camera in a position such that field of view corresponds exactly the window, and the whole box can be used as a unit. Any ordinary range finder or reflex viewing system can be used for focusing. Since the air in the boat makes it very buoyant, it will be easier to control unless weights are attached around the bottom. A focusing hood is usually necessary to prevent reflection of the sky on the window. Reflected images of reflex cameras might try a reflected image of such a box with the window the side instead of in the bottom. The camera placed on the bottom is pointed
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out through the window. The photographer looks down into the ground glass screen. The box must be big enough so that the operator can reach down into it and work the camera's controls.

Of course, these boxes and buckets can be used only to photograph objects that are near the surface, but most good picture possibilities occur in this zone, anyway. The light falls off rapidly as we go down, and the color of the light changes, growing more and more bluish. As I have mentioned, these effects vary greatly from one time and place to another, so it is impossible to make up any useful tables. But the very marine life we are interested in photographing depends on sunlight, too, and most of it is to be found in shallow water.

Below about twenty feet—the exact depth varies with the clarity of the water—natural light becomes too faint to use and the photographer must depend on flash or speed light. These sources work nicely under the water if enclosed in suitable housings, but the pictures taken with them usually exhibit all the disadvantages of terrestrial flash pictures, much magnified. The foreground is unnaturally bright, while the background is dark; textures are subdued where they should be brought out; and the shadows are in all the wrong places.

The best solution is to keep the flash away from the camera. Some flash units have telescoping arms that can be extended, but they are difficult to maneuver and even harder to swim with. It is often helpful to have a second diver hold the flash, although directing him is a problem, for one has to rely on hand signals. Since no one should ever dive alone, anyway, the photographer may as well put his companion to work.

Despite its many difficulties, under-water photography can be an exciting experience, and the results can be impressive, as the many published examples prove. The best under-water picture becomes truly miraculous when one considers the obstacles that were overcome to make them. Most experts, if they really let their hair down, would agree that the "secrets" of successful under water photography are:

1. Work in shallow water. In many cases the best photographs, the surface of the sea is just out of the frame.
2. Shoot only at close distances. A long shot probably won't come out.
3. Take plenty of time. Practice using your equipment in a warm swimming pool at the beach before you go farther out.
4. Take a good friend. Make careful tests and have them developed as you work. Finally, don't expect more than one good picture a day. By that one picture can be worth it.

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THE JOURNAL OF THE AMERICAN MUSEUM OF NATURAL HISTORY

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COVER: The jagged mountains of Baltistan, a remote region of High Asia, loom above Balti boatmen poling a skin raft across a river. This photograph was made by James Hurley during one of his five visits to the country. Sometimes called Little Tibet, Baltistan is inhabited by a people remarkable for its admixture of Caucasian and Mongoloid racial traits and for its language, which belongs to the Tibeto-Burman family but is written in Arabic letters. Although the Balti of today are all Moslems, previous religions have included totemism, Bon, and Buddhism. Mr. Hurley's study of Baltistan and its population starts on page 13.

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Among the 2,600,000 visitors to the Museum and Planetarium last year were heads of state and heads of households; tourists from Bangkok and teachers from Brooklyn; children standing for the first time at the gateway to science; parents sharing the joy of discovery; and grandparents renewing their early experiences.

On a Sunday afternoon last fall Crown Prince Akihito of Japan, guest of honor at the new Japanese exhibit in the Hall of Birds of the World, saw an exact replica of an area to the north of Mount Fuji in an exhibit that includes thirty different species of birds. Not long afterward Prime Minister Nehru paid a visit to the Planetarium and was shown the autumn skies over India reproduced on the dome. Another recent visitor, the Supreme Patriarch of Thailand, expressed keen interest in all the exhibits he viewed, from dinosaur footprints to lunar landscapes.

During the coming months Museum visitors from near and far will see new exhibits that range in subject matter from “Art and Life in Old Peru” to “Man in Space.” The Peruvian exhibit contains rare treasures culled from private collectors and museums in Peru and the United States, many of which have never before been displayed. Our own collection will yield a good deal of this material, including examples, never before shown, of the oldest patterned textiles from the New World. These are fabrics excavated by Dr. Junius Bird of the Museum from the Huaca Prieta mound in Peru. Through his microscopic analysis Dr. Bird has demonstrated that fabrics are the oldest known medium of artistic expression in Peru. It is a long step from life in ancient Peru to life in a space ship, but a Museum visitor will be able to make the transition very quickly.

The exhibit “Man in Space” will have as its main feature a full-size model of a five-man space laboratory, known as ARIES (Authentic Reproduction of an Independent Earth Satellite). The cylindrical model is forty-one feet long and fifteen feet in diameter. Revealed through its transparent shell will be the major part of the life-support system needed to keep a five-man team afloat for 60 days, while they conduct experiments on a variety of biomedical problems that man will encounter as he probes space, looking for new frontiers of basic knowledge about the universe.

Through such exhibits, a Museum visit becomes a memorable personal experience. But this institution’s role in teaching natural history extends beyond its halls. Across the country, people of many backgrounds are served by the Museum through a score of extension services and communications media. Most recent of these is The Natural History Library, published in cooperation with Doubleday and Company. This distinguished series of reprints of natural history classics, selected by Museum scientists, is attractively presented in colorful paperback format, thus making available to a wide public books of enduring interest in the life and earth sciences.

To encourage a sense of discovery in all who come within its sphere is a basic aim of the Museum. A favorite Museum headline, therefore, was a recent one involving three New Jersey teen-agers who were exploring an abandoned quarry and uncovered what turned out to be the fossil remains of a gliding reptile older than any previously known to science. The young men, who had been pursuing their fossil-hunting hobby under the aegis of Dr. Edwin H. Colbert of the Museum, recognized immediately that their find was a significant one. With infinite care they cut the rock to portable size, embedded the specimen in plaster, and brought it to the Museum. Here, a skilled technician, using a device resembling a miniature sandblasting machine, spent three months at the task of cleaning the fossil and exposing the delicate skeleton. After an exhibit arranged to give the public a chance to see the fossil, Dr. Colbert began an intensive study of it. His work on the 175,000,000-year-old fossil will be published in our scientific series and should shed light on a whole new facet of vertebrate evolution.

The discovery itself was of paramount importance, but equally so were the circumstances, which seemed to us so clearly representative of the Museum’s purpose. Three young boys, whose curiosity had been aroused and whose interest in science had been heightened so that they knew enough to value what they found, came upon a rare scientific treasure. Because of their quest, many other youngsters will come to respect the lessons of the past as well as look forward to the promise of the future.

Alexander M. White
President
More solid reading between soft cover

By CHRISTOPHER GEROLI

The flowing river of "serious" paperback books, which was already a healthy stream a year ago, has now completely overflowed its banks. All major publishers seem presently to be involved in the paperback business, as are many specialized firms, notably the university presses. The reading public, superficially at least, has never had it so good.

Unfortunately the paperback output is subject to the law of diminishing returns as well as to the law of supply and demand. The reservoir of titles worth re-printing is not boundless and, as a result, there is an increasing number of paperbacks of questionable value—dated textbooks and popularizations, as well as works of quite limited interest.

Basically, of course, these problems concern the publisher and the unhappy bookseller who must find room to display the exponentially increasing output. But there are serious corollary problems for the reader as well, including the critic as a specialized reader. The most obvious problem is simply how to find one's way round. In the first place, what has been published? For a quarter, the reader can get part of the answer from the subject index edition of Paperbound Books in Print (R.R. Bowker Co.), which is available in most stores specializing in paperbacks. The Bowker catalogue lists some 11,000 titles and is issued several times a year. Obviously it can never be entirely up to date, since publishers' plans change, but it is the best source for what is available.

Another quarter, mailed to the American Association for the Advancement of Science at 1515 Massachusetts Avenue, N.W., Washington 5, D.C., will bring a copy of An Inexpensive Science Library, prepared by the AAAS and The National Science Foundation. This annotated bibliography lists some 500 titles in 29 fields, and the current (fourth) edition is complete through July 1, 1960. To our knowledge, this is the only descriptive source available with listings in the biological sciences—although its notes are very brief. Beyond these two aids, the reader is reduced to finding his own way through the jungle. The review that follows is a necessarily limited attempt to note some of the more recent and more interesting additions to the paperback library since the last summary published here (NATURAL HISTORY, June-July, 1959).

A useful sourcebook on classical astronomy, ending with the nineteenth century, is Arthur Berry's A Short History of Astronomy (Dover, $2.00). A hardly perennial among textbooks, it has the positive merit of treating the work of men like Kepler and Newton at length and the defect of a rather prosy style. Another Dover publication in the field of astronomy is interesting on two counts. An Elementary Survey of Celestial Mechanics, by Y. Ryabov (Dover, $1.25), is a crystal-clear exposition of the basics in a field that is much less esoteric than it was a few years ago. The mathematics do not go above high school level, and the text includes worked-out computations of the orbits of artificial satellites—using the early Sputniks as cases in point. Even lacking an interest in the subject, the thoughtful American reader might spend an hour or two pondering the differences between this interesting but no-nonsense Soviet presentation and some of the angel food cakes that pass for popularizations here.

The popularizations of George Gamow are far above the pastry-cook standard, since the author is a physicist of repute as well as an accomplished and witty writer. At the same time, his One, Two, Three . . . Infinity (New American Library, 50c) tends to another kind of superficiality by attempting too much in too short a space. The reader who follows Professor Gamow through a jet-propelled tour of modern mathematics, cosmology, nuclear physics, microbiology, genetics, and other fields, risks either an unwarranted feeling that he knows all about everything or the sensation of a plain case of indigestion.

One of the better paperback science ventures is the "Ann Arbor Scien Library" series, published by the University of Michigan Press. All are written by European authorities, are made physically, and are well illustrated. The Sun, by Karl Kiepenheuer and Planet Earth, by Karl Stum (Michigan, each $1.95), typify this series. Stumpf's book is particular interesting to the biologically minded reader in its terse but detailed account of the environment in which we live.

Still in the general field of astronomy one of the classics of popular science The Universe Around Us, by Sir James Jeans (Cambridge, $1.95), is now available in soft covers. It remains the best account of modern astronomy available anywhere. Modern theories of the creation of the universe, as well as such topics as the earth's radiation heat only recently mapped, are treated in The Universe at Large, by Hermann Bondi (Doubleday, 95c). The book is somewhat smaller than its title, both in scope and accomplishment, being a compilation of magazine articles by a British astronomer.

Bondi's book is a volume in the "Science Study Series," produced under eminent sponsorship with the purpose of making up-to-date and authoritative texts in modern science available to secondary school students and the general public. One of the best of the set is The Restless Atom, by Alfred Ron (Doubleday, 95c), a history of the 165 years of progress in nuclear science. In this case the historical approach lends extra clarity in a field that is always somewhat difficult for laymen.

Another approach used in this set is the biographical. Pasteur and Modern Science, by René Dubos, and Michell and The Speed of Light, by Bernd Jaffe (Doubleday, each 95c), offer...
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Interesting contrast of the tremendous scope for experimental differences in creative scientific research. Pasteur’s work covered an enormous range, including the foundation of the science of crystallography as well as his better-known pioneering in microbiology and immunology. He also was the archetype of the scientist as a public servant, discovering the technique of partial sterilization by “pasteurization” while attempting to improve the notoriously doubtful quality of French beer. By his table, Michelson’s achievement rested almost entirely on the utmost refinement of laboratory work in the measurement of the speed of light and the development of new instruments and techniques in physical optics. But Michelson’s effect was quite as far-reaching as Pasteur’s, since he laid the groundwork for much of modern theoretical physics.

Another paperback series pointed toward the schoolroom is entitled “Foundations of Modern Biology” (Prentice-Hall, each $1.50). Each hundred-odd-page volume concentrates on a single topic, giving it fuller treatment than is possible in the average college text for an introductory biology course. Typical titles are The Plant Kingdom, by Harold C. Bold, an outline of classification, structure, and methods of reproduction; The Cell, by Carl P. Swanson, covering the basic organizational unit of living matter; and Animal Growth and Development, by Maurice Sussman. The serious amateur of natural history will find in this series information on specific fields, including the latest research.

The increasing group of amateur microscopists will have a special interest in Milestones in Microbiology, edited by Thomas Brock (Prentice-Hall, $3.95). Here, abbreviated and well annotated, are most of the major papers in this fascinating field, from van Leeuwenhoek’s first description of “several sorts of little animals” in a drop of water, through Robert Koch’s classic “Methods for the Study of Pathogenic Organisms,” on to Fleming’s discovery of the bactericidal effect of Penicillin mold. Neither a text nor a history of microbiology, this book is a good introduction.

Specific groups of animals and plants have come in for attention—one definite plus value of the spate of paperbacks. One of the better specialized volumes is The Molds and Man, by Clyde M. Christensen (Minnesota, $1.75). The fungi, all 90,000 of them, are among the most interesting of plants, and both easy and rewarding to study. Christensen writes of them with an enthusiasm that borders on gush, whether he is discussing the unique combinations that compose lichens or explaining that the flavor of Camembert cheese derives from two molds, one a Penicillium.

Insect Life and Insect Natural History, by S.W. Frost (Dover, $2.25), basically a college level entomology text, is a useful supplement to standard field books; while Mollusca, by J.E. Morton (Harper, $1.40), can serve similarly for the devoted shell-collector. Neither is really readable.

So many good books have been written about ants that another would hardly seem necessary. Nevertheless, The Ants, by Wilhelm Goetzch (Michigan, $1.95), is a good book, particularly in its descriptions of ant behavior, which the author has observed in many parts of the world. The Birds, by Oskar and Katharina Heimroth (Michigan, $1.95), in the same Ann Arbor series, casts a broad net to gather in a variety of facts, and is at its best in relating bird structure to bird behavior. Reptiles: Life History, Evolution, and Structure, by A. Bellairs (Harper, $1.35), has value as a systematic account of this class but, again, this work is for reference.

Two good but specialized field books are How to Know the Ferns, by Frances T. Parsons (Dover, $1.25), and California Spring Wildflowers, by Philip A. Munz (California, $2.95). The Parsons book, originally published more than 60 years ago, maintains its value through the simple accuracy of its drawings, The Munz book, based on the California littoral, is a cause for jealousy on the part of residents of other areas—a good text and nearly a hundred well-chosen and handsomely reproduced color photographs back up its black-and-white drawings.

Meteorology is perennially attractive to the curious amateur, but books on meteorology are all too often over-detailed for the beginner. By focusing on the more spectacular aspects of weather, Louis J. Battan, in The Nature of Violent Storms (Doubleday, 95c), manages to concentrate a large amount of modern weather science into comparatively few pages and to do so in interestingly. Weather plays its part in Water: The Mirror of Science, by Kenneth S. Davis and John A. Day (Double day, 95c), a truly imaginative piece of science popularization. The authors discuss the role of water in many different sciences, as well as the extraordinary physical and chemical properties that make water essential to life and a dominating factor in both the human and geological history of the earth.

The same interdisciplinary approach distinguishes another in the “Science Study Series,” Waves and the Ear, by Willem A. Van Bergeijk, John R. Pierce and Edward E. David, Jr. (Doubleday...
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...nibalistic habits of Australopithecines as in recalling the slightly less lethal behavior of embattled anthropologists.

Among the earliest nature books were the medieval bestiaries, omnivorous compendiums of observation, travelers' tales, and pure mythology. *The Bestiary*, translated and edited by T.H. White (Putnam, $1.50), comes from a twelfth-century Latin manuscript and retains the flavor of the original's wide-eyed wonder at the diversity of nature. The editor, a notable medievalist in his own right and author of *The Once and Future King*, has selected more than 125 illustrations from manuscripts to embellish the text, and has contributed footnotes that are informative and entertaining.

Unicorns and fire-dwelling salamanders, however, are not mandatory for the creation of a bestiary, *Nature Parade* by Frank W. Lane (Fawcett, 50c) collects facts from serious scientific sources and manages to be quite as marvelous as any medieval invention. Not the least wonderful member of the animal kingdom, according to Mr. Lane, is man—who can generate 8½ horsepower, exert a bite of 534 pounds pressure, and eat a meal consisting of a raw sheep, a suckling pig, and 60 pounds of prunes.

Another of man's accomplishments unique in the animal kingdom, his ability to devastate his own environment, either loudly in a matter of milliseconds or quietly over the centuries. The latter type of ruin, usually accomplished with such weapons as saws and plows, can be quite as final as the blast wave and the mushroom cloud. How this can be so is the theme of John H. Storer's *The Web of Life* (New American Library, 50c), a primer in ecology and the study of the labyrinthine interdependences of the earth and the living things upon it. The conclusions it draws are as important—and in some ways more immediate—than the cold war headlines of today's newspaper.

Two very different classics in modern "nature writing" are available in "Explorer Books"—a series notable for physical quality and readability. *Flowering Earth*, by Donald Culross Peattie (Viking, $1.15), calls itself "a biography of the plant kingdom." Mr. Peattie, a better naturalist than prose-poet, is most interesting when his subject matter can be glimpsed through the pale-purple guaze of his verbiage. *The Outermost House*, by Henry Beston (Viking, $1.25) is perhaps the kind of book Mr. Peattie intended to write; sensitive, direct, poetic without poesy. It tells of a year spent quietly between sky, land, and sea on the dunes of the Atlantic side of Cape Cod, with little except the birds, the surf and the weather for company.

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ce paperbacks, above, The American Museum of Natural History takes plea-

er in announcing that a new series of self-cover editions, "The Natural History Library," has been initiated. With Mu-

seum scientists cooperating as advisers, Double-day Anchor Books last month published the first thirteen reprints in a series of classic studies in the natural sciences. Some of the titles are being especially revised for this series; most will have forward-written by members of the Museum staff. Running widely through the natural sciences, the selec-

tions focus on man in his environment.

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In connection with the review of scien-

ce paperbacks, above, The American Museum of Natural History takes plea-

er in announcing that a new series of self-cover editions, "The Natural History Library," has been initiated. With Mu-

seum scientists cooperating as advisers, Double-day Anchor Books last month published the first thirteen reprints in a series of classic studies in the natural sciences. Some of the titles are being especially revised for this series; most will have forward-written by members of the Museum staff. Running widely through the natural sciences, the selec-

tions focus on man in his environment.
Snowlike targets seen outlining coast of Massachusetts are "angels"—echoes of birds on a radarscope, photographed on night of unusually heavy movement.
The Migration of "Angels"

Radar offers new data on bird movements

Most people have a general understanding of how radar works, and many have seen pictures of a radarscope, or Plan and Position Indicator (PPI). As the radar beam—which is roughly analogous to the sweeping beam of a lighthouse—passes a target, be it ship, airplane, or even bird, that target is "illuminated." With radar, the illuminated target appears as a bright spot on the PPI scope, and the target's distance and bearing are thus shown on a "map" of the area around the radar installation. Many of the bright spots that appear on the modern PPI scope are readily identified. Still, particularly with high-powered radar, there are often many small, unidentified spots. Because these spots do not move as expected targets would, they have come to be known to radar observers as "angels." A photograph of a PPI scope of the experimental radar at South Truro, on Cape Cod, is shown at the left. In the picture, the Cape appears dark against the large number of light spots, or angels. These targets, as it happens, are birds.

Argument as to the nature of angels has raged ever since these cryptic targets were detected on the south coast of England in 1940 and 1941. Early experimental radars picked up gulls, herons, and gannets, all of which are very large birds. The British ornithologists Lack and Varley published a paper in 1945 on the detection of gannets at coastal defense radar installations. But, despite this and many other articles describing the appearance of birds on radarscopes printed soon after World War II, most radar operators were (and still are) unwilling to believe that birds could be responsible for the displays of angels. Instead, these spots have usually been attributed to little-understood meteorological phenomena, and so dismissed.

Only in the last few years has the circumstantial evidence pointing to birds as the major cause of angel displays become overwhelming. And only in 1957 was systematic experimental evidence produced. That year, a team of research workers at M.I.T.'s Lincoln Laboratory, including one of the authors of this paper, conducted a year-long experiment that demonstrated that most angels are due to birds. The group then devised a circuit that would filter out radar echoes corresponding to targets the size of birds. When this circuit was inserted in the experimental surveillance radar installation at South Truro, Massachusetts, the angels disappeared.

Previous to this 1957 experiment, however, several studies of the daily and annual migrations of angels were published, showing just how valuable radar could be to the ornithologist. In 1956, Emil Weitnauer verified the suggestion that swifts regularly spend the entire night on the wing. After tracking angels in the night sky over Switzerland, he was eventually able to intercept the targets in a small airplane, and found that they were indeed swifts. E. Sutter, another Swiss ornithologist, published the first radar studies of bird migration in 1957. In England, the radial dispersal of starlings and rooks was studied by W. G. Harper in 1957; while that of New World blackbirds was observed in Michigan by Elder in 1957, in Texas by Ligda in 1958, and in Tennessee by Cypert the same year. The movement of these gregarious birds from their common roosts, as tracked by radar, resembles the exten-
As all of this work has shown, radar can provide much interesting information on a variety of bird habits. Migration that occurs at night, or at altitudes too great to be seen from the ground, has heretofore been an ornithological unknown. The studies made so far have revealed in a most vivid fashion the tremendous volume of migration that can take place, so to speak, behind the unaided human observer's back. One of the most spectacular examples is Lack's discovery of a huge spring flight of chaffinches, skylarks, and other winter visitors, from England eastward to the Continent—phenomenon that had barely been suspected by earlier students.

Radar's remarkable ability to trace the movements of individual birds and to display echoes of all the birds in a wide area, promises early solution to several long-standing problems of migration today. Measurement of the altitude of angels, for example, suggests that most small northward migrants fly between 1,500 and 6,000 feet—with a sprinkling of birds some nights as high as 10,000 feet. Lack's work shows that birds migrating from England across the North Sea to the Continent do not correct for the drift effect of cross-winds, but are deflected laterally from a more or less constant heading, so that they move northeast when the wind is from the south, or southeast when it is from the north. We find vivid illustrations of the same type of wind-drifting of birds out to sea off Cape Cod (illustration, right).

Our own opportunity to carry out radar research on bird migration grew from the previously mentioned experiment at Lincoln Laboratory, as part of the development of the SAGE A Defense System. The team at Lincoln concluding that angels were birds, were able to relate daily movements of the targets to those of herring gulls and ducks that feed off Cape Cod. They apparently having solved the problem of the angels, they were puzzled, in March, 1957, to find a much larger number of smaller angels moving in a northeast direction. The rightly concluded that this represented...
the spring migration of land birds, and that its detection by radar would interest ornithologists.

So far, analysis of nightly films—the PPI scope record of a whole night’s migration can be compressed into a few minutes of film—has been concerned with three main problems. The first is chiefly statistical—the relationship between the true number of migrating birds and the density of angels on the screen. On a good night for migration, there may be 100 or more birds aloft per square mile. If every bird were detected, the entire scope would be swamped by echoes. The compensating factor, which resolves this difficulty, is due to a phenomenon that is well shown in photographs of the radar screen. As distance increases, progressively fewer birds are detected, so that the pattern of echoes thins out steadily until the density of angels can be counted easily. This is because the radar’s sensitivity falls off at longer ranges. Preliminary results show that, if the density of birds is constant, the number of angels is roughly halved in each ten-mile step from the center of a PPI scope.

Thus one may count the number of angels in a given area, multiply this number by a constant factor, and so obtain a reasonably reliable estimate of the total birds passing over the area. Having obtained a count of angels in this way, we made an independent estimate of the number of passing birds by counting those birds visible through powerful binoculars trained on the moon’s face and applying a mathematical correction to this visual count. Although such a method of sampling is probably less accurate than techniques of observing migrations visible during the day, the results achieved by scope and visual methods agree very well.

We decided that each angel corresponds to something between three and 12 birds when the angel is at approximately 20 miles. Because radar should easily be able to detect individual birds at such short ranges, this greater-than-unity result suggests that many of the birds travel in small groups. At the same time, it is unusual for the visual observer to see even two small birds cross the moon together. We therefore conclude that these night flocks must be a good deal more scattered than the large flocks of many daytime migrants.

Our second problem concerned what radar tells us of the behavior of birds when they reach a coastline. On a night of heavy migration, the density of birds overhead is approximately one per acre. Thus, migrating birds must be greatly concentrated before a ground observer will be aware of the fact that a migration

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**Actual flight path of bird is plotted, above, to show the effect of cross-wind on bird’s original course toward coast.**

**Daytime movements of wind-shifted night migrants, noted by ground watchers, suggest birds then head for mainland.**
has taken place. Students of migration, being naturally attracted by large numbers, have in the past sought out places where migrants are concentrated by certain natural topography features. Van Dobben, in 1955, showed how these concentrations may occur under certain circumstances in Holland. He pointed out that if a group of birds, migrating on a broad front, meets a coastline, perhaps one in four or five birds will turn and move along the coast, while the rest cross without deviation. The single observer, stationed along the shore and counting the birds coming down the coast, might well report a heavy coastwise migration and little evidence of birds crossing the coast, because he sees most of those birds that have turned from all the way up the coast and only a few that cross the beach where he is. From such observations the conclusion has been drawn that many parts of the world that migrants come from inland to the coast and follow it as a migratory route. (This conclusion has been especially prevalent in the eastern United States.)

The turned birds, if they continue along the coast, will eventually be concentrated by the accidents of topography, and such places of concentration will have become familiar to students of migration. Quite often these places also concentrate the and unusual birds of interest to raptors. For example, the east coast of Sweden—on the main migration route—is not nearly so good a place to find stragglers from Siberia as the small islands off the Norwegian coast, Fair Isle, off the north coast of Scotland. And the famous names, Helgoland, Monomoy Point, Nantucket Cape May, Island Beach, reflect other such misleading samples.

Our radar studies showed heavy movements pouring across the coast in late spring and fall, without any reaction to the coastline except by a very small percentage of the birds. In the fall, for instance, songbirds often appear pouring south over the Atlantic in waves that would seem to be a dangerous weapon. This finding, in itself, offers a new problem in migration that was even suspected before the use of radar. The fate of those sea-bound songbird populations is not presently known, though there is a hint that, toward dawn, birds turn west and northe as if seeking the shore. This geographi
with the observation of those who have watched daylight movements along the New England shore. These observers often report birds coming in from the sea all through a fall day, heading in a northwest direction—when birds "should" be heading southwest at this time year.

In contrast to the previously held belief that birds come down to the coast and then turn to follow it as a route, our radar studies show that between 10 and 50 times as many small birds—coming from Maine, Nova Scotia, and Newfoundland—migrate southwest, over Cambridge and the inland areas of Massachusetts, as pass over Cape Cod. This is at least circumstantial evidence that migrant populations as a whole tend to follow routes away from the coast. Banding results seem to confirm this: at inland sites in the fall, adult birds may nearly equal the immatures; but coastal banding stations have long known that they should expect 95 per cent or more of the fall population to be immatures—as if the older birds seemed to "know better."

Spring radar observations show heavy migrations leaving Cape Cod in a northeasterly direction toward Nova Scotia without any hesitation at the coastline, although there are even heavier movements inland at such times. We may conclude, then, that the main populations select their general movements to avoid the dangers of being blown out to sea; and although the average bird probably pays no heed as it passes over the coast, the actions of individual birds—when watched in detail—may be different.

Still another group of birds ignores the coastline for their own special reason. Radar sometimes shows dense, fast (40 knots) targets flying out to sea on southeast courses in the late afternoon, especially about an hour before rain squalls. These targets occur particularly from mid-July until mid-October, and they are sandpipers and plovers on their non-stop flight to the Lesser Antilles and South America. Sportsmen on the outer islands, such as Barbados, have long known that these shore birds came in, but they did not know how far they had come.

The third problem we have studied is the direct effect of weather on migrant birds. It has long been known, of course, that migrant birds are greatly affected by weather changes, rain and bird traffic as seen on radar. Peaks are correlated with clearing after rain; clouds and wind seem secondary.

Weather's influence on migration in spring, graphed above, reveals a close correlation between days of state-wide

Fall migration pattern in relation to weather conditions, above, shows close similarity to spring's. Note that cold map this September, however, brought southerly movements of kind that are more commonly found during October.
and that night migratory movements are correlated with the movements of air masses. But the collection of precise facts and fine details has been greatly handicapped by observational difficulties. Radar now provides a reasonably good quantitative measure of nocturnal migration, and opens the way to a new study of the problem. Lack in England and Sutter in Switzerland have already provided important data on the relation between weather and migration in Europe, and the first results are beginning to come in from North America.

The chief source of our weather information is the U.S. Weather Bureau's daily map that shows the 1:00 A.M. readings of temperature, cloud cover, precipitation, and strength and direction of surface wind for a wide range of stations. Actually the wind at a height of 1,000 to 4,000 feet is more relevant to the movement of birds than the surface wind, but upper air movements can be deduced with fair accuracy from the map's isobars while, in special cases, we have obtained aerosonde readings from local weather stations. Since we can measure the birds' flight directions and the speeds, and we assume that they left shortly after dark, we can trace them back to the approximate places where they started to migrate. We may then determine the weather that affected birds before and during that flight.

A summary of outstanding interactions between weather and migration over certain areas of New England in May and September, 1959, our first year of operation, will give some idea of the possibilities opened up through radar techniques. In general, our results confirmed conclusions made as long ago as 1888 by Wells Cooke: the nights of the largest spring migration were those of clear skies and steady movement of warm, tropical air in a northeast direction from the Middle Atlantic States. We have long known that migrants usually stop when they meet precipitation, heavy cloud cover, or turbulent winds. An example is on the night of May 7-8 when favorable conditions existed to the south but ended sharply at the Massachusetts-Rhode Island border. Large numbers of birds appeared in Rhode Island while, to the north and east where the weather was cool and overcast, relatively few birds appeared. The unaided ground observer could properly have interpreted the events of that night. But of special interest is the frequency with which radar results disagree with the impressions of ground observers, who judge the strength of the night's migration by counting the grounded migrants seen the following day. A vivid example of the dangers of this method was given us on the days 9 through 14 May. The nights of May 9/10 and 10/11 were increasingly good for migration, and the radar recorded very dense movements of birds. But ground field observers found only insignificant numbers of new arrivals on 10 May and 11 May. On the succeeding three nights, May 11/12, 12/13, and 13/14, the weather was still warm with favorable winds, but conditions in the Central Atlantic States were too cloudy to be ideal for the start of migration, while a stationary front over eastern Massachusetts produced heavy clouds and rain—a major barrier to migrating birds. Field observers in New England found the largest number of birds of the spring of 1959 after the night of 13/14 May. But the radar showed relatively small numbers of birds had been migrating that night! These results suggest that conventional techniques of field observation overemphasize the importance of "spectacular" waves of migrants, which can be produced for enumeration by the premature interruption and grounding—by rain—of even a small movement of birds.

Both the New England spring and fall are celebrated for their violent contrasts in weather. The spring arrival of a cold front brought new phenomena of outstanding interest. On three occasions when such weather occurred (the nights of 8/9, 14/15, and 22/23 May, 1959), the radar showed a steady southward movement, with many birds even heading southeastward out to sea. This parallel with autumn movements is reflected in the ground observations. In southern Rhode Island, where spring migration is always sparse—the autumn migration is much more interesting because the east-west coastline interrupts some birds' southward flight—the best days of the spring were 10, 16, and 23 May, 1959. It is easy to suggest that there may be a selective advantage for insectivorous birds—having advanced too rapidly in the spring and being overtaken by weather that threatens their food supply—to react by returning southward immediately. The reaction was certainly a rapid one. On the night of 22/23 May, when the cold front crossed over Cape Cod at about 11:00 P.M., the northeastern movement of birds was replaced, first, by a milling movement as the squalls of rain associated with the front passed, and then by a southward movement—all in a period of about two hours.

Radar has revealed similar reverse migration in the autumn. In September, 1959, the birds were moving north-east during periods of warm weather as tropical air entered from the south-west. The records of the nights of 9/10 and 12/13 September show just how delicately the movements of the birds are adjusted to weather conditions. On these nights, there were cold fronts lying along an east-west line over the Gulf of Maine. In the cool, Canadian air to the north and east of the front, radar showed birds moving southwest from Nova Scotia while, to the southwest, in the warm, tropical air lying over Rhode Island and Connecticut, the birds were moving in a northeast direction from Long Island toward Cape Cod. Such radar observations solve the ancient dilemma between the theory (supported by field observations) that, in the fall, birds should be going southwest, and the hard facts of banding recoveries that often show a fall movement to the northeast. For the biologist, however, a further problem is raised: if birds can reverse movements so easily, what internal factors control orientation?

Like most new tools of science, radar has already raised more ornithological questions than it answers. But, above all, it has given us an unequaled opportunity to relate actual migration to the experiments provided by the foibles of New England weather, and to watch with some precision a natural phenomenon that has intrigued men for at least as long as written records have existed—the movement of birds in the night sky.

Weather conditions that influenced migrants during May, 1959, are shown right. Radar revealed modest volume of flights, but ground observers counted record number of rain-grounded birds.

MAY 8/9: Cold front from north brought reverse movement.

MAY 10/11: Conditions generally favorable to migrants.

MAY 13/14: Rain grounded migrants across New England.
The People of Baltistan
A transitional culture of Central Asia
By James Hurley

High Asia was introduced to much of the world only seventy years ago in a book by E. E. Knight called Where Three Empires Meet. Although one of these “Three Empires”—that of the British—has now passed away, recent moves in High Asia by the Chinese have revived interest in the area. Yet knowledge of this remote region has remained remarkably unchanged since the latter nineteenth century. Knight’s work, which became almost a textbook for more than a generation of British school children, was mainly concerned with Hunza, a tiny mountain principality that was situated athwart the meeting place of British India, Russia, and China. But Knight also touched briefly on Baltistan, or Little Tibet, a fascinating and still relatively unknown region lying off the main routes and passes, then, as now, out of the main political arena of the contending powers.

Who are the Balti and why did their country sometimes called Little Tibet? Briefly, the Balti are of mixed Mongoloid and Caucasian racial stock, they speak a language of the Tibeto-Burman family, and they are followers of the prophet Mohammed. This unusual combination of race, language, and religion probably exists nowhere else in the entire Himalayan and Trans-Himalayan region. In fact, Baltistan is one of the important transition areas between East and West; it marks the farthest westward extension of the Tibetan language and culture, and quite possibly the farthest eastward penetration by the Caucasoids into one of the most formidable mountain bulwarks on the world’s surface. One can well imagine how painfully slow must have been their progress if one looks at a relief map that shows the successive complex of the Hindu Kush, Pamir, and Karakoram ranges, which thrust innumerable ice-capped ramparts, high glaciers, and deep gorges in the way of any intruders into the region.

**[Map of High Asia with Baltistan highlighted]**

Raised canal near Skardu, capital of Baltistan, is three miles long. Dating from the 1500’s, canal was reputedly built by Skardu’s last Buddhist queen.
But do we have any idea how and when these light-skinned people with origins so similar to ours reached this region in the first place? Generally, we do not. Possibly they were a later offshoot of those Aryan tribes that streamed from their upland homes north of the Iranian Plateau, into northwest India across the Khyber and other low passes to the southwest about 1500 B.C. Balti tradition has it that some of the local rulers and petty chiefs are descended from the soldiers of Alexander the Great, but there is no evidence to support this and the claim seems to be almost completely in the realm of wishful thinking.

The first references we find to the Balti occur in the reports by the second-century writer Ptolemy who, in his Geography, mentions "the Byltai" and "the Daradai." He gives no details of the former, but the latter seems clearly to refer to the Dards, a people of Caucasoid stock. The Dards now dwell mainly in the Gilgit region to the west of Baltistan, but also they constitute a fairly sizable and distinct minority within Baltistan. Herodotus, some 600 years earlier, had also referred to the area of the Dards when he wrote about the country of the "gold-digging ants" (creatures as big as dogs, who threw up gold while burrowing holes in the earth). Most authorities interpret the location of the area described in this passage as the Deosai Plateau, which lies largely within the confines of Baltistan. Until we learn of an earlier people, we can assume then that it was the Dards who constituted the original Caucasoid population of Baltistan, upon which successive layers of invasion, trade, and proselytizing have produced the present curious mixture.

We next hear of the Balti people in the account of the travels of the seventh-century A.D. Chinese Buddhist pilgrim Hsian Tsang. Aside from the fantastic legends that have sprung up about his trip (so delightfully translated recently in Arthur Waley's The Monkey), Hsian Tsang's observations about the people, route features, and historical circumstances of the time still remain among the most valuable and sometimes the only
sources of knowledge—not only for remote places such as Baltistan, but also for many areas in India as well. Journeying from northwestern India to Baltistan in about a.d. 632, Hsüan Tsang recorded: "... after climbing precipices and crossing valleys, we go up the course of the Sin-tu [Indus] River; and then, by the help of flying bridges and footways made of wood across the chasms and precipices ... we arrive at the country of Po-lu-lo [Bolor or Baltistan]. It stands in the midst of the great Snowy Mountains. It produces wheat and pulse, gold and silver. Thanks to the quantity of gold, the country is rich in supplies ... the people are rough and rude in character; and as for politeness, such a thing has not been heard of. They are coarse and despicable in appearance ... their letters are nearly like those of India, their language somewhat different. There are about a hundred sangharamas [monasteries] in the country with something like a thousand priests, who show no great zeal for learning and are careless in their moral conduct."

Not a very complimentary passage, but it does provide us with facts on which we can almost surely rely. Although historical circumstances have changed greatly over the last 1,300 years, much of what Hsüan Tsang said is still appropriate. For example, the difficulties of the route along the deep Indus gorge between Gilgit and Skardu are virtually the same. Hsüan Tsang's comment on the language, especially interesting in that it may refer to the Tibetan script (which was adopted from the Indian) and thereby indicate that Baltistan had already been subject to Tibetan influence for a considerable period. Whatever script was used—and we know almost nothing of what it was—it has long since been discarded (probably about the time of the Moslem conversion), being considered a relic of idolatry.

Baltistan enters the picture again briefly but dramatically, in the eighth-century annals of the T'ang Dynasty. During the sixth and seventh centuries, China had been extending its sway over the western region—Turkistan, which included present-day Afghanistan and western India. As early as the T'ang, the Chinese began to regard the regions in which the Buddhist sangharamas were located as an outlying province of their empire. This view may well have been fostered by a desire to study the religious methods and beliefs of the Buddhist monks of the great monasteries. In 780, the monks of the T'ang court included a number of representatives of the Buddhist sangharamas of Baltistan in the imperial service. The value of this service lay not only in the actual contributions of the monks to the imperial administration, but also in the opportunity to learn the religious and cultural aspects of the region. This was a time of great interest in the West, and the T'ang court was eager to obtain as much information as possible about the region. The monks of Baltistan were a valuable source of information, and their presence in the imperial service provided a means of obtaining this information.
Kashgar, Khotan, Kucha, and Karas- shar. Between A.D. 696 and 741, the Balti, fearing attack from the Tibetans, sent several missions to the Chinese court. One of the results was the conclusion of a marriage alliance—always important in the East—between a Baltic prince and a Tang princess. The Tang rulers also sent 4,000 Chinese soldiers in A.D. 722 to assist the Balti in repelling the Tibetan invaders. But all was for nought, and the Tibetans overran Baltistan in 737. Ten years later, in 747, the area changed hands again when a Chinese force re-established Tang influence.

The year 747 was an important one in Central Asia, for that August a force of 10,000 Chinese, under the Korean general Kao Hsien-chih, crossed the formidable barrier of the Pamir and Hindu Kush to the west and wiped out the Tibetan garrison at Gilgit. The political importance of this event was great, for it came at a critical time in history and forestalled a tie-up between the Tibetans and the rapidly advancing Arabs on the west, who were already in western Turkestan. It is difficult to imagine how the face of Asia might look now had there been a joint Arab-Tibetan invasion of China. The Chinese march into Gilgit is equally remarkable as a feat of logistics. It marks the only time a major military force has crossed this continental divide between China and India, and it has been held to compare with, or even surpass, the great Alpine feats of such commanders as Hannibal and Napoleon.

However, the Chinese victory was only temporary: within a few years they were thrown out of Turkestan, not to return for more than a thousand years. In A.D. 751, Baltistan was permanently overpowered by the Tibetans. Thereafter, there are no references to the area in Chinese annals. In fact, for the next six centuries Balti history is almost a complete blank. We know nothing of how long the Tibetans stayed, what the nature of their rule was, or what cultural interpenetration took place. It has been surmised that the Tibetan occupation was relatively short and that the suzerainty exercised was nominal. This seems a reasonable premise in view of the great distance—more than 2,000 miles—separating Baltistan from Tibet’s center, Lhasa. Of even more historical relevance is the fact that, by the end of the ninth century, Tibet’s power—and with it that mountain nation’s one serious bid to be a world power—had passed. But even during this brief period, we may assume that much of the racial admixture we see now in Baltistan had taken place.

The blank of the next few centuries is not even penetrated by Marco Polo. That notable medieval traveler and observer, when he passed several hundred miles to the north in the thirteenth century on his way to the court of Kublai Khan, made only the briefest reference to the mountainous area of Bolor lying to the south. He gave no geographic details of this region, but earlier students of his travels thought Baltistan might fall within it. The modern view, however, is that Polo meant only the country lying between the great bend of the Indus (at Gilgit) and the Pamirs.

Not until the end of the fifteenth century do we begin to get some sort of sketchy idea of the Balti in their present historical setting. It was then that the new Moslem rulers of Kashmir began to take an interest in their mountain neighbor to the northeast. The Hindu kings who had ruled Kashmir up to the middle of the fourteenth century may have exercised loose control over the Balti from time to time but, on the whole, Baltistan had probably retained its independence. Now the Moslem sultans looked at it possibly with an eye to linking up with eastern Turkestan, where the population had embraced Islam some time during or soon after the wane, in the ninth century, of Tibet’s monarchy.

For unknown centuries before this Moslem influx, the Balti had been Buddhists. We know this mainly from carvings and graffiti on rocks—showing such typically Buddhist subjects as funerary monuments and bodhisattvas—which are still visible at several places in Baltistan (the large one near Skardu, shown on pages 22-23, is considered the finest example). We have no direct evidence as to when the Balti became Buddhists, but it appears to have happened sometime between the fourth and seventh centuries. Hsuan Tsang’s reference to the priests and monasteries, already quoted, is the only positive clue. But these rock carvings also tell us something else: they indicate the existence of an earlier, pagan religion. Among the crude figures carved on the rocks, now little
Ibex figures are inscribed on a rock near Kuru. Carvings may be connected
more than traces, the figure of the ibex occurs most often. The meaning of
these ibex signs, which are said to occur from Siberia to Palestine, is dis-
pputed among anthropologists. The
theory that seems most current is that
the symbol is connected with an early
totemistic cult having the ibex as a
sacred animal. Recent research tends
to conclude that the domestication of
the goat occurred first in these high
regions of Asia; thus, it is not difficult
to imagine how the ibex, the most
lordly of the goat family, became an
object of veneration. But local tradi-
tion and legend do not go back so far;
they ascribe the depictions merely to
the work of shepherd boys, or some-
times connect them with hunting. For
example, after a local raja has killed
a minimum of perhaps 100 or 200
ibexes to prove his prowess, each sub-
sequent kill is commemorated with a
carving. In nearby Gilgit, the carving
of the ibex still takes place before the
hunting season as a symbol of luck or
expiation. One legend, from the ad-
joining area of Ladakh, has it that one
of the incarnations of the Buddha is
an ibex, while another declares that
the ibex is connected with fertility, a
figure being carved whenever a child
is born to a couple who had sought
divine intervention.

Between the development of these
early animistic and totemistic cults
and the adoption of Buddhism in the
early centuries of our era, another
religious system seems to have exist-
ed in Baltistan under the name of
Bon. Essentially the worship of nat-
ural forces—earth, fire, and water
(with which the colors blue, red, and
white were associated)—it originally
took the form of primitive shamanism.
Although remnants of Bon beliefs still
exist in Tibet, nothing is known about
the religion's connection with Baltis-
tan except that certain place names
are believed to be associated with ritu-
al names in the Bon religion.

One great legend survives that may
yet prove an important key to
the Bon as well as the Buddhist period
of Baltistan's history. This is the Kesar
saga. An epic poem dealing with the
life of the mythical Tibetan King
Kesar, it has been said to be to Asia
what the Iliad is to Europe. Kesar has
become the present-day national hero
of the Tibetans, comparable to the
British Arthur, the Hebrew David, and
the Persian Rustam. In her book, The
Superhuman Life of Gesar of Ling,
the French Buddhist Alexandra David-
Neel relates dramatically how the
"yellow races" (Tibetan, Mongol, and
Chinese) consider Kesar as a sort of
messianic figure, or latter-day Geng-
ghis Khan, who will return some day
to lead them against the whites. The
Balti, fortunately, do not have that
bent, but think of Kesar merely as a
former Buddhist or pagan king. Their
present Moslem faith forbids their at-
taching any religious importance to
Kesar, but his hold on their imagina-
tions is clear in the large number
physical features with which his na
is still associated: "Kesar's gun," "K
sar's horse," "the place where Kes
shot the arrows," and "Brugmo's ne
lace" (Brugmo was the bride of Kesar,
are some of them.

In recent years, however, Kesar's
place in Balti folklore has been
creasingly challenged by the name
Syed Ali Hamadani, one of the great
Moslem figures of the fourteenth cen-
tury, traditionally held to be res-
sponsible for the conversion of Balti
Islam. Although the survival of
lengthy and unwritten Kesar seems
to recite it in its entirety takes ten
twelve to twenty evening sessions.
strong testimony to Kesar's stay
power, it, too, seems to be disap-
ing under the pressure of incre
Islamic activity. During four suc-
sive yearly trips to Baltistan, I fo
no one who knew the poem in its
 entirety. It was only with the consi-
able assistance of a local raja that
managed to collect the epic last y
The challenger of Kesar, Syed Ali
Hamadani, was a remarkable per-
ality who combined the qualities
mystic, missionary, and practical
former. He was born in Hama
...at about A.D. 1000, Buddhism was evanent from 4th to 14th centuries.

Persia, in A.D. 1314, the son of a local governer. He became interested early life in Sufi mysticisam, and turning to sweling as a way to acquire knowledge, undertook many long trips. The most important was his visit to Kashmir.

More than any other person, Syed Ali may be said to be responsible for ringing the eyes of Kashmir westward the Islamic cultural centers of Persia. Shawl weaving—the word Kashmiri (cashmere) has since become a word for quality woven goods—as possibly introduced by him. It was this period that some of the other ts and crafts that today make Kashmir the delight of tourists (papier-mâché and decorative metal work, for example) were also introduced. It seems likely that they came from Tamberlane’s capital, Samarkand. Since merclane was then importing artisans from Damascus, it is hard to escape the conclusion that some of these imposed Arab craftsmen, or their descendants, may have gone on to Kashmir.

Syed Ali’s first trip to Kashmir was in A.D. 1372. After a stay of a few months, he returned to Persia. He came again in 1379 and 1382, each time staying more than a year, then going home via Turkestan. This latter fact is significant in relation to Baltistan and the date of its conversion to Islam. The customary route to Turkestan from Kashmir was through Ladakh and over the Karakoram Pass. Baltistan has passes to Turkestan, but these are generally higher and more difficult to traverse, and have been long unused. Furthermore, in published records of Syed Ali’s life and journeys, there is no mention of his having visited Baltistan. Yet the Balti have innumerable stories and legends about places Syed Ali visited, miraculous feats he performed, and mosques he built. In addition, there are natural features with which his name is associated, such as “the place where Syed Ali rested his walking stick,” and “the place where Syed Ali stuck the arrows in the cliff.” Some of these—the latter example, in particular—are confused with places associated with Kesar.

Since the next important Moslem figure does not appear on the scene in Baltistan for another century and a quarter (ca. A.D. 1505), I thought it might be possible to find out the exact route or routes taken by Syed Ali on his alleged visit or visits to Baltistan. Therefore, over the last three years, I have questioned the literate Moslems—mullahs, rajas, teachers—and other Balti on the point. The results are mystifying. In every valley it seems there is a tradition of Syed Ali’s having come that way. Of the tales told by the many people with whom I spoke, hardly any two were the same. So the question of Syed Ali’s presence in Baltistan remains open—probably answerable only through detailed examination of his own writings or those of his contemporaries regarding his travels.

The later history of Baltistan is a record of the growth of sects, petty wars with the Ladakhis and the Kashimiris, subjugation by the Mongols of Turkestan and later by the Moguls of India, the coming of the British to India and the attendant return of Kashmir to the Hindus and, finally, in 1947, the reconquest of northern Kashmir and Baltistan by Moslem soldiers. This resulted ultimately in the current administration of Baltistan by the recently created Moslem state of Pakistan.

Among the key events of this period was the arrival in Kashmir—and subsequent banishment to Baltistan in A.D. 1505—of the Persian envoy and Sufi missionary Mir Shamsuddin’lraqi. Next to Syed Ali Hamadani, he is the best-known Moslem figure of Baltistan. It was apparently he who popularized a new sect, the Nur Bakhshiya, that purported to present a middle road between the major Islamic schools, the Sunni and the Shi’a. At one time this sect comprised the entire population of Baltistan. Its origins are shrouded in mystery, for it was persecuted and banned in Persia during the early years of the sixteenth cen-
Mr. Hurley, now a student at the University of London's School of Oriental and African Studies, has visited Baltistan five times. His first four visits were made while he was stationed in Pakistan with the United States Foreign Service.

tury, and its remaining adherents have been incognito ever since. Indeed, the Nur Bakshiya sect exists now as a functioning body only in Baltistan.

Another interesting figure of sixteenth-century Baltistan was Ali Mir, the Raja of Khapalu. By his exploits and energy, he may be said to be the greatest lay figure in Baltistan's history. During the latter part of the sixteenth century, Ali Mir dominated not only all of his own country (which, both before and after him, had usually been divided up among rival petty rajas), but he also exercised suzerainty over what is now Ladakh, or Indian Tibet. Ali Mir's importance may be judged from the fact that he married one of his daughters to the Mogul Prince and later Emperor Jehangir—no mean accomplishment for a mountain chieftain. Another of Ali Mir's daughters was married to the King of Ladakh. From this union came two subsequent rulers, Sengge Namgyal and Deldan Namgyal, who were destined to lead diminutive Ladakh to the pinnacle of its power and influence.

It is evident from the variety of national strains mentioned here that no simple answer to Balti racial origins is possible. But research on this question has been going on for the last 100 years and some progress has been made. To summarize the findings briefly: from the early idea that the Balti were primarily of Mongoloid extraction, the Austrian Baron Ujfalvy's expedition and researches of the late 1370's pushed the pendulum to the other extreme, saying they were almost entirely Caucasian. The measurements made by the Italian professor Giotto Danielli in 1914 counteracted this, showing a strong admixture of Mongoloid characteristics in certain areas. Now, English scientists—using the newer method of blood type comparison—promise to shed further light on this vexing but fascinating problem; they hint at correlations with the Kirghiz and Uzbeks of western Turkestan, which is now considered a part of Soviet Central Asia.

(To be concluded in November)
I center, is the site of the ancient fortress-castle of the Raja of Kharnang.
A substantial advance in the discovery of the universe could logically have been expected from the invention of the reflecting telescope; the skill and indomitable spirit of William Herschel transformed this advance into the most spectacular forward leap in the history of astronomy.

German-born (at Hanover, in 1738) and raised to be a musician, Herschel left his war-torn country at the age of 19 to seek a career in England, where he eventually secured the post of concert director at the fashionable resort of Bath. Although his interest in astronomy had been little more than a hobby at first, Herschel found himself increasingly absorbed in the subject until, in 1782, he resigned his post to devote all his time to scientific pursuits.

By then, Herschel had already acquired an international reputation for his discovery, in 1781, of the planet Uranus. His principal interest, however, was concerned with the study of stars and other celestial objects outside the solar system. To that end he designed—and built in his own workshop—a number of telescopes of ever-increasing size. It must be remembered that, in astronomy, the magnification of a telescope is secondary to its light-gathering power, for the latter is proportional to the area of the mirror and governs the amount of light that is concentrated into a star’s reflected image. Therefore a larger telescope allows one to see fainter stars, and thus, on the average, permits the observer to penetrate deeper into space.

With his superior instruments, Herschel undertook systematic studies on every conceivable astronomical subject—on planets and satellites in the solar system, on the nature of the sun, on the motion of the sun in space, and on double and variable stars. His major contribution to cosmology, however, came from his efforts to ascertain what he termed “the construction of the heavens.”

Until Herschel’s time, stars had been treated as so many pinpoints of light inside a hollow sphere and as convenient reference marks for orientation. Little thought had been given to their distribution in depth. Intrigued by the appearance of the Milky Way, which he saw as a brilliant band of faint stars girding the celestial sphere, Herschel explained its appearance as an optical illusion created by an effect of perspective. He pointed out that if stars, including the sun, are distributed in a relatively thin stratum or layer, an observer would see a great condensation of stars in all directions within the stratum’s plane, but only a few scattered ones at right angle to it. The result would be, of course, a narrow circular band of stars in the sky.

He even assumed that the layer was forked at one end, in order to explain the so-called “Great Rift of the Milky Way” in the constellation Cygnus (see diagram at left above). We know now that the Rift is caused by the interposition of a dark nebula, but the existence of nonluminous clouds in space is a modern concept.

The next task was to determine, if possible, the general shape of the stratum. For that purpose, Herschel introduced a sampling system, which he called “star gauges.” His procedure consisted in sweeping small sections of the sky and performing an actual count of the number of stars in the field of view of his telescope. Considering that one instance he found as many as 588 stars in a field about one quarter the size of the full moon, and that he extended his sweeps over the entire sky, one may well imagine the enormous extent of this undertaking.

By using his star gauges, Herschel acquired a rough idea of the three-dimensional shape of the Milky Way. As a working hypothesis, he assumed at first that stars are evenly distributed within the volume of our Galaxy; the...
the number of stars counted in a given gauge could be interpreted as a measure of the distance to which the Galaxy extends in that direction. A comparison of his star counts in various parts of the sky led him to the sketch (diagram at right, above) of our disk-shaped stellar system as the utter would appear to an edge-on viewer.

In reality, stars are often found in clusters, and it cannot be said that they are evenly distributed. On the other hand, inner stars, on the average, are also farther away; thus they are more numerous than the brighter ones in a given area of the sky, because they represent a greater volume of space. As a consequence, Herschel’s results did not ray far from a true picture of the system.

Much of Herschel’s career was spent refining these views on the structure of the universe. Many of the objects that he had first seen as small, nebulous patches came clusters of faint stars when he observed them again with larger telescopes. So confident was he in the power of his instruments that he assumed, sooner or later, he would be able to resolve all nebulae into star clusters. This was not to be, of course, since many of these objects are indeed diffuse masses of luminous gas. Herschel himself established this fact by simple reasoning when he drew a star surrounded by a ring of nebulosity.

The fact that light does not travel instantaneously had been known for about a century when Herschel discussed is observations of nebulae and clusters. He used this property to point out a phenomenon, which has become familiar to the modern astronomer; namely, that one does not see a distant star as it is now, but as it was when the light rays left it. Applying this fact to his own research, he classified all nebular objects in decreasing order of brightness and assumed that he had obtained in this manner an evolutionary sequence, the fainter objects being also the younger. Later investigations did not confirm his results because he was unable to distinguish the various categories of nebulae and clusters, but the principle of associating increasing distance with lesser age is now a classical method in the study of the evolution of galaxies.

It is worth noting that, from a theoretical standpoint, Herschel’s concepts on the structure of the Galaxy and the nature of nebulae and clusters were not original. A few decades earlier, the Englishman Halley had pointed out that some of the nebulae seemed too large to draw their illumination from the faint stars observed within them, and must therefore be self-luminous. In France, Pierre de Maupertuis, doubting that all nebulae could be resolved into stars, concluded that they must be amorphous masses much larger than individual stars, since one can observe their outline in spite of their great distances.

Finally, Immanuel Kant, in Germany, proposed the correct explanation of the appearance of the Milky Way and assumed that other “island universes,” similar to our Galaxy, might also exist. But in most cases—contrary to Herschel’s approach—these theories resulted from speculations ranging far beyond the meager data available.

Toward the end of his career, Herschel said once “I have looked farther into space than ever human being did before me.” Yet his greatest achievement lies not so much in that—an adroit gadgeter, with a suitable urge, could have built just as large or a larger telescope—but in Herschel’s extraordinary ability to interpret his observations. Little was added to the concertmaster-cosmologist’s discoveries until the development of spectroscopy and the invention of photography opened up the modern era of astronomy.
THE SKY IN OCTOBER

From the Almanac:

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<tr>
<td>Last Quarter</td>
<td>October 1</td>
<td>9:10 A.M., EST</td>
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<tr>
<td>New Moon</td>
<td>October 9</td>
<td>1:53 P.M., EST</td>
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<tr>
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<td>October 16</td>
<td>11:35 P.M., EST</td>
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<td>October 23</td>
<td>4:31 P.M., EST</td>
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<tr>
<td>Last Quarter</td>
<td>October 31</td>
<td>3:59 A.M., EST</td>
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For the visual observer:

Mercury, in Virgo, will be poorly placed for observation, except for a few days at the end of October. Setting a scant forty-five minutes after the sun on October 1, it will be at inferior conjunction on October 22 and will enter the morning sky on that date. By October 31, it will rise about an hour before the sun. Its magnitude will brighten rapidly in the last few days of the month, from +1.5 on October 26 to +0.7 on October 31.

Venus (—3.4 magnitude) will be a morning star all month, rising at 3:30 A.M., local standard time, on October 1, at 4:00 A.M. on October 15, and at 4:30 A.M. on October 31. It will be visible in the eastern sky before sunrise.

Mars (magnitude +1.5) will set in the west about thirty minutes after sunset throughout the month of October. It will be too close to the sun for observation.

Jupiter (—1.9 magnitude), in the constellation Capricornus, will be low in the southern sky at dusk, setting in the southwest at midnight on October 1, at 11:15 P.M. on October 15, and at 10:30 P.M. on October 31.

Saturn (+0.8 magnitude), in Sagittarius, will be about 5° west of Jupiter. Thus it will precede that planet by about twenty minutes during October.

Observation of the Orionid meteor shower, on October 20, will be hampered this year by a bright, gibbous moon. Under more favorable circumstances, as many as twenty-five meteors per hour might be seen by a single observer.

Morning and evening stars:

According to the astronomical definition, a planet is said to be in the evening or in the morning sky if it crosses the local meridian before or after midnight, respectively. Although this definition holds true for all planets, it is simpler, in the case of Mercury and Venus, to say that they are in the morning sky if they rise before the sun, and in the evening sky if they set after the sun.

The expressions morning and evening stars reflect a traditional usage, which dates back to ancient times, when planets were believed to be "errant stars." To this day, in popular lore, these terms have been applied almost exclusively to Mercury and Venus—particularly the latter.

The astronomers of ancient Greece were well acquainted with the fact that Venus could be seen both in the evening and the morning sky, and recognized it in both instances. But the Greek poets, on the other hand, were accustomed to calling the morning star "Phosphoros" and the evening star "Hesperus," without regard for their being two aspects of the same celestial body. Rather than being mere poetic license, these names must owe their origin to the beliefs of yet earlier times, when men were fully convinced that Hesperus and Phosphoros were different bodies. Only in these ancient days did the expressions morning and evening star have any logical meaning: they have been nothing but misnomers ever since.

On the preceding pages, Mrs. Gossner offers the eighth in her 1961 series on the growth of cosmological concepts.
MAGNITUDE SCALE

★ -0.1 and brighter
★★ 0.0 to +0.9
★★★ +1.0 to +1.9
★★★★ +2.0 to +2.9
★★★★★ +3.0 to +3.9
★★★★★★ +4.0 and fainter

PICTURE: AUSTRINUS

TIMETABLE

<table>
<thead>
<tr>
<th>Date</th>
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<tr>
<td>October 1</td>
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<tr>
<td>October 15</td>
<td>9:00 P.M.</td>
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<tr>
<td>October 21</td>
<td>8:00 P.M.</td>
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(local Standard Time)
FROM THE UNPARALLELED COLLECTIONS OF THE AMERICAN MUSEUM OF NATURAL HISTORY...REPRODUCTIONS OF PRICELESS HANDICRAFT FROM THE CULTURES OF AFRICA, TIBET, CHINA AND JAPAN. DECORATIVE AS WELL AS CULTURALLY SIGNIFICANT. THESE REPRODUCTIONS ARE LONG LASTING TREASURES.


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THE AMERICAN MUSEUM OF NATURAL HISTORY, N.Y. 24
This is the 112th of Nature Magazine's special educational inserts
There must be few of us, indeed, who at one time or another, have never seen, touched, or perhaps experimented with spiders and their webs, the subjects of this educational insert. These animals and their gossamer creations may be secured at any time of the year, and they furnish study material that costs nothing. There are few zoological subjects about which there is more misunderstanding, and it is difficult to find simple information about them in printed sources. It is the webs that will be emphasized in this insert.

In size, certain spider webs may measure up to several feet in width. They may be constructed with a marvelous engineering skill, and are designed to assist in the protection, food-getting, transportation, and other affairs of their makers. Their study can afford pleasure, wonder, and a challenge, and prove well worth the necessary time and effort. We must consider the nature of the materials used by spiders in making their webs, and the source of those materials. We should be able to recognize the engineering aspects of spider webs, the functional part they play in the lives of spiders, and the role, if any, they have played in human affairs and literature.

Obviously, it should prove easier to find a four-foot spider web in the woods than to find its maker, whose body may measure less than an inch in length. If, therefore, the reader would like to know more about spiders, it might first be well for him to learn to recognize webs.

One-third of the spider webs considered in this insert look like huge spoked wheels with spirals arranged in the spokes. Two other types of webs are platforms, or being found most commonly indoors, and the other more commonly outdoors. One spider builds a platform supported above and below by strong stays, although the web as a whole has only a vague design. Two spiders build webs that are irregular open nets, common placed over an opening in a wall, or under a log or rock. Two other spiders build delicate "bowls," one kind this right-side up, with a platform beneath it, and one bottom-side up, but so porous that captured insects may be pulled through it by its maker, who hides beneath.

One species of spider builds a web only as a cow for the nursery in which its young are confined and guarded. However, most of the webs discussed in this article are traps of one sort or another; and it should be added here that there are about as many types of we as there are of spiders. Correlatively, a spider may tentatively be identified by the kind of web it makes, and closely related spiders make webs that resemble one another to a greater or lesser degree.

Dr. E. Laurence Palmer, for many years director of Nature Magazine's educational program, continues his special inserts in the pages of the combined magazines.
There are many types of webs that cannot be discussed here. There are also many spiders that do not make webs of a conspicuous nature; some make webs only for special purposes or at special times.

There are few places where active spiders may not be found at some time of the year. Certain spiders may even live—although they do not build their webs—in the snow. Of the spiders listed in the chart section of this insert, the southern house spider, *Ariadna*, the squint-eye spider, the domestic platform spider, the black widow spider, the house spider, and some of the members of the family Araneidae are most likely to be found in houses and barns. Meadows and lawns are favored by grass spiders, which build nets with trip-threads stretched above them in the grass. The trip-threads are designed to upset insects so that they fall into the net, to be captured and eaten. Woodlands are the habitat of triangle spiders and the filmy dome spiders, while the vicinity of waterways is likely to be favored by the long-jawed orb-weavers, fishing spiders, and others. Some water spiders are able to walk on the surface of water, while others can dive below the surface to capture the animals upon which they subsist. These latter may even carry a supply of air with them for use in their submarine pursuits.

**Temperature** may affect the activity of some spiders, but in general the animals prefer temperatures that humans find pleasant. To determine the temperatures at which spiders are most active, put one in a deep glass container, such as an empty olive bottle. Put a thermometer in the bottle, and pack cotton into the bottle's throat, so that the spider cannot escape. Move it from the refrigerator to a warm oven, first determining the room temperature. This will give the temperature range at which the spider is most active.

Spiders have rather definite light preferences. Some species favor darkness, and others light. Many may begin to move when the light fades, and their activities must then be observed with the aid of a flashlight. Much of the construction and repairing of webs takes place during the hours of darkness.

Rain, fog, and dew may affect the webs of some spiders by adding weight to an already well-taxied and flimsy structure. Many spiders select sheltered, dry locations for their webs, a circumstance that indicates their attitude toward water. However, spiders must have access to a certain amount of water to stay alive, and if specimens are being kept captive for observation, it is well to dampen cloth, cotton, or blotting paper and put it where it may be visited by the animal. Spiders can usually survive starvation better than desiccation.

The food of most spiders is animal matter. However, few attack large animals, and apparently prefer to eat smaller prey, such as the insects that are snared in their nets. Some spiders have been known to exist for months without food with no observable difficulty.

The bites of some spiders may be poisonous, but for the most part a spider bite is harmless. As far as a spider is concerned, its poison is most useful to quiet the struggles of a prospective meal. Spiders have many ways of capturing, quieting, storing, and eating their food; but those interesting activities cannot be considered here. Suffice it to say that a spider, detecting a captured in-
sect, may come out on the web, bite the prey, throw some silk around it, and then return to its lair. If the prey continues to struggle, the spider will emerge, bite it again, throw more silk around it, and return to the lair.

Spiders are remarkable creatures of habit. Occasionally mammals as large as mice allow their tails to become entangled in a spider web. The spider goes through the routine outlined above, each time strengthening the attachment to the mouse and giving it a pull. In this way mice, snakes, and other relatively large animals have been captured and killed by diminutive spiders. With a little concentrated observation, the habit pattern of almost any spider may be easily investigated.

Some spiders are sensitive to certain noises. Often a spider will drop from its web to the ground when a certain musical note is sounded, and different notes affect different kinds of spiders. Some most interesting studies of the reactions of spiders to sound have been made at Harvard University.

The general life history of spiders is well worth learning. For most spiders, life begins in a silk egg cocoon that is crowded with eggs. This mass of eggs is almost always protected in some way from the elements. Hatching temperatures are variable; some of the beautiful orb-weaver spiders of our summer gardens were hatched from their eggs in a weed-top cocoon in the coldest part of the year. Other species may hatch at almost any temperature at which life can exist.

Since spiderlings find themselves crowded together in a cocoon with no special food stored away for them, they merely wait until another egg hatches and then eat a helpless brother or sister. This continues until the more aggressive spiderlings free themselves from the cocoon. From the beginning, a spider’s life is a hard one; but obviously the survival rate is sufficient.

Once free of the cocoon, the young spider faces an uncertain future. Some younglings may cling to the backs of their mothers, and thus be carried about. They may spend some time in a silken nursery, protected by the watching mother. They may move about on the web made by the adult, and feed on food scraps found there. Or they may begin to shift for themselves at once, without ever having seen their parents.

As small spiders move about and secure food, they increase in size. Since their skeletons are on the outside, they cannot gain flesh; when they grow they must shed the exoskeleton and develop a newer and larger one. This process continues at least until the animals are mature. Mature males are usually much smaller than females, and the lack of equality between the sexes is noteworthy. Sometimes a courting male is not welcomed by a prospective mate, and she may eat him. In some species the female eats the male after mating. It is not necessary for mating to take place prior to each egg-laying, since the fertility of the female may continue for some time. A spider may live for a number of years.

Reproduction is one phase of a spider’s life; securing food is another. A spider must eat and at the same time avoid being eaten. To understand something of the intricacies of food-getting, let us consider the unwelcome fly that buzzes about your house. You do not want it there, but some spider wants it for a meal, and has various means by which to capture it.
Basic to all spider webs is spider silk, one of the most remarkable substances to be found in nature. (There are some spiders that make little use of silk, but they will not be considered in this insert.) In the spiders dealt with here, silk is ordinarily produced by one or more of seven different types of glands. Usually these glands have shapes that have given them their names, and each may have a special function. Some may be limited to spiders belonging to particular families; also, some spiders have more kinds of glands than others.

Among the silk glands found in spiders are those that are berry-shaped, those that are pear-shaped, and others that are bellied, cylindrical, tree-formed, or lobed. The berry-shaped glands are to be found almost universally. They produce a silken swathing band useful for binding a victim quickly, and may feed into middle or rear spinning tubes, which may number from a few to hundreds. There may be four clusters of such glands, having from a few to many glands to the cluster.

The pear-shaped glands are also found in many groups of spiders. They are in two clusters, each with from one to many glands that feed spinning tubes whose openings are in front of those of the berry-shaped glands. The silk from these glands serves in the production of attachment discs for the strands of silk. A series of four-, six-, eight-, or twelve-bellied silk glands is generally found on the silk producers, except in the hindmost spinning tubes. These glands produce the great draglines and the dry threads of the webs. They may also be responsible for the production of elastic silk, some of which can be stretched up to fifty times its original length. These glands, like the others mentioned, are common in most silk-producing spiders.

Some silk glands are more specific than those mentioned so far. There are, for example, sets of certain cylindrical glands that may number up to six or more in a female, and fewer—or none at all—in the male. These, like the bellied glands, open through spigot tubes. Since they produce the silk used in making the egg sac, they are not necessary to the males, which do not produce such a sac. They are also absent in a few families not included in the list covered in the chart section of this insert. The cylindrical glands open on the middle and rear spinning tubes.

Tree-form tubes—four large and two small—open into the rear spinning tubes. They have pointed tips, indicating the need of specific placement, and produce he particularly sticky drops needed by members of the Theridiidae, the Linyphiidae, and the orb-weavers. The swathing film that is characteristic of spiders related to the house spiders—and which the animals throw over a prospective meal—is produced by two- or four-lobed glands that feed one or two spinning tubes near the rear. These glands feed through a spigot-like tube.

Some of the silk in the webs of the first two species considered in the accompanying chart section has a lace-like appearance because of the presence of a series of loops spread on more substantial strands. To help in the production of this type of silk, another gland may be found in a few species of spiders. This is called the tregibulum, and it opens on the underside of the body forward of the other glands described. With the silk from these seven types of glands, spiders can travel, eat, pro-
tect themselves, communicate, protect their young, and meet the important problems of a spider's life.

A walk down a woody path in summer will almost certainly bring you into contact with a strand of silk, stretched across the path from one tree or tall plant to another. You may wonder how it could be placed there. Did the spider attach one end of its thread to a tree, drop to the ground with the thread still attached to it, run up the other tree, and pull the silk tight across the path? No. How much simpler for the spider to select a point from which it can spin a thread of silk that may be blown across the gap by the wind. When the free end of the thread comes in contact with a support, the line can be tightened and a pathway established that is strong enough to support the spider. This may perhaps be the spider's first step in making a web. Such an initial line must be cast when the wind is favorable.

Once the first line is established, the spider can drop a second vertical line by letting it down on its own silk. From this lower point a second horizontal line can be established parallel to the first, and then a second vertical line can be established in the same way as the first. This completes the basic square. Students of orb webs call such lines "foundation lines," and the whole web may be built within this square. If the lines are to support the whole web, it is important that they be sufficiently substantial to stand the strain—and they are. Once the frame is established, the rays and spirals may be made with comparative ease. As a rule, the rays are not sticky; but some—and sometimes all—spirals are.

It may be noticed in the accompanying illustration that the spirals are quite variable. In some instances there is an area at the center that is free of spirals; here the spider may rest and await its prey. In some cases the center may be filled by a particular kind of web of which the spider may rest. In some webs, the spirals are continuous from the centers outward. In others, the spider may use one kind of thread in the spiral and fill alternate areas with another kind—perhaps alternating one dry thread with one sticky thread. In the case of the golden-silk spider, one thread may be one color and another a different color.

A glance at the sketches of the webs will show many variations in the spirals. On some webs the spirals are made by the spider circumnavigating the web in only one direction, while in others the spider may occasionally double back. Where the spirals place a strain on the spokes, it is important that lateral strain should not be from one direction only. This engineering problem is shown in the detail of the web of the golden-silk orb weaver Nephila, in which colored, sticky spirals are easily differentiated from white, non-sticky spirals.
In studying the webs of the orb-weavers in the genus *Micrathena*, and some others, it may be seen that some of the spokes are connected by a conspicuous unit of silk that the spider may shorten or lengthen, depending on whether the web must be loosened or stretched more tightly. This is the stabilimentum, and its placement in the web varies. It sometimes appears on both sides of the center, and sometimes on one side only.

The web of *Zygiella* merits special study. It will be noted that the spiral thread in this web fails to close the gap between two of the radii. Down that gap extends a strong line reaching from the hub of the web to a silken retreat, open at each end but placed out along the foundation line. In this case, the spider can rest in the retreat from which it can escape in either direction, and yet it has a communication line with the hub of the web, and can quickly reach a place in the web where a potential meal has been ensnared.

In *Araneus*, the web exhibits a variation of this arrangement. The spider is outside the original foundation lines, but is still connected by communication lines with the hub of the web. This arrangement guarantees the spider greater safety without lessening its awareness of any activities occurring on the web.

In *Tetragnatha*, there is an interesting variation of the orb web. While ordinarily the orb web is placed more-or-less vertically, in *Tetragnatha* it is commonly tipped over toward the horizontal. Since the web of this spider is commonly spread over running water, the horizontal position better serves to catch insects that are usually found in such places. Can any of the readers imagine why this should be the case?

In studying the various webs, the student should not fail to notice the clever way in which *Aradina* manages to keep its web free, even though it ordinarily lies close to a stone or other surface. He should also study the web of *Hypothees*, a splendid sort of trap in which the spider stands ready to shake its triangular sheet-web to entangle its prey in the sticky cross-threads. The exploration of an old barn or cellar will certainly reveal the loose, irregular web of a house spider, or that of *Pholcus*. If something is dropped into the web, the spider may come out and jump up and down in the web in great excitement. This is the way the spider manages to throw at least one thread around an intended prey.

The reader who studies spiders and their webs will doubtless marvel over the behavior patterns of these creatures, and their differences in anatomy and web construction. If he will read various books about spiders, he will find how spiders and their webs differ one from the other, and also how the authors differ in their interpretations of the phenomena they observe.
<table>
<thead>
<tr>
<th>Spider Name</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>Southern House Spider</strong>&lt;br&gt; Filistata hibernalis&lt;br&gt; Family Filistatidae</td>
<td>Silken sac larger than spider but smaller than retreat hole is suspended in retreat by radiating, paired threads to 6 inches or longer, extending to more than 6 inches from sac to a remote attachment. Threads may stretch to 50 times original length. They are covered with hooked loops and a sticky sheath. Male pale tan, to 2/5 inch long. Female dark brown, with dusky patches on back and black fuzz beneath, to about 4/5 inches long. Over-all length, to 2 inches. Legs stout. Eyes do not come together in one group. Legs about 2 times body length, with front pair the longest. Silk of 4 kinds in web, which soon dries.</td>
</tr>
<tr>
<td><strong>Arianna</strong>&lt;br&gt; Ariadna bicolor&lt;br&gt; Family Segestriidae</td>
<td>Retreat hole slightly larger than spider is lined with long, slender, silken tube suspended by threads from retreat wall and bordered at mouth by silken collar. Many strong radiating threads are supported by 2 or more piers. Whole structure is sensitive to touch. Male to under 1/3 inch long, with female under 2/5 inch long with long oval abdomen. Purplish brown above and below; part of side gives species “bicolor” name. Forward 3 pairs of legs directed ahead permit speedy emergence. Legs lighter than body.</td>
</tr>
<tr>
<td><strong>Triangle Spider</strong>&lt;br&gt; Hyptiotes curvatus&lt;br&gt; Family Uloboridae</td>
<td>Web basically a 4-pronged fork suspended between dead twigs, with unusually long handle to keep web taut, and with 10 to 20 separately installed cross threads, connecting prong—each doubled and with hooked bands—and sticky threads. Spider shakes web by agitating the handle. Adult female to 1/6 inch long, male to 1/10 inch, resembling dead buds of tree—usually an evergreen—in twig crotch of which web is suspended. But for web, adults would be hard to find. Female’s abdomen has double row of rounded bands which are much less developed in male.</td>
</tr>
<tr>
<td><strong>Squint-Eye Spider, Pholcus</strong>&lt;br&gt; Pholcus phalangioides&lt;br&gt; Family Pholcidae</td>
<td>Webs to a number of feet in diameter, highly irregular, loose and open, in which spider hangs head or back down. Old webs heavily dust-laden. Web shaken violently by spider when potential prey becomes entangled, further trapping the animal. No egg cocoons are found hanging in web. Male body to 1/4 inch long, female to 1/3 inch. Abdomen length twice its width, with sides usually parallel and rear blunt. Slender legs, to 2 inches long, give animal appearance of daddy-long-legs. Body pale brown to straw-colored. Grass web in center back. Leg joints contrast.</td>
</tr>
<tr>
<td><strong>Grass Spider</strong>&lt;br&gt; Agelenopsis noevia&lt;br&gt; Family Agelenidae</td>
<td>Silken platform to 3 ft. or more across, basically of strong, nearly in length of slender threads from lower spinnerets that are crossed in all directions by a mesh of finer threads from upper spinnerets. Supported by grass or other objects. Retreat for the adult is in a rather short tube that hangs from one side of the net. Male to 3/5 inch long, female to 4/5 inch. No need to spin web. Rear pairs of legs. Color varies from light yellow with pale gray markings to dark reddish brown with black and gray spots or stripes. Often has conspicuous band down back. Leg joints are dark.</td>
</tr>
<tr>
<td><strong>Domestic Platform Spider</strong>&lt;br&gt; Tegenaria domestica&lt;br&gt; Family Agelenidae</td>
<td>Densely woven layer of silk often broken by weight of dust and trash. Edge of web lower, higher, or on level of web body. Escape and hiding tube is at one side, close to the outside shelter. Commonly found in corners where they are not disturbed by animals, including one prime enemy, man. Body of female to nearly 1/2 inch long, male to 2/5 inch long. Legs give spiders over-all length to over 1 inch. First and 4th pair of legs about 2 times the body length, finely banded and hairy. Light yellow-brown, with 2 gray, longitudinal stripes on body. Male abdomen smaller than that of the female’s.</td>
</tr>
<tr>
<td><strong>Fishing Spider</strong>&lt;br&gt; Pisaurina mira&lt;br&gt; Family Pisauridae</td>
<td>No snare web is built. Large nursery web a foot or more in diameter may be constructed, enclosing the whole top of a good-sized weed. This protects the hidden egg sac and emerging spiderlings during early days of their lives when they first become completely independent of cocoon. Males and females almost the same size, with the slightly larger female 3/5 inches long. Yellow to light-brown with a dark-brown, broad, median band on the back. Abdomen is margined with white. Median area around eyes as long as its rear width. Some varietal differences within the species.</td>
</tr>
<tr>
<td><strong>Black Widow Spider</strong>&lt;br&gt; Latrodectus mactans&lt;br&gt; Family Theridiidae</td>
<td>Web irregularly spread net with funnel-shaped retreat area, usually placed in protected spot. Often or frequently placed over opening through which prospective prey might be expected to pass. Web not elaborately zoned for particular purposes, as are other web types. Female body to 2/5 inch long, male to 1/5 inch. Female shiny black with red spots and usually the familiar red hourglass mark beneath abdomen, but this may be reduced and varied greatly, or spots may be entirely absent. Spider hangs feet upward in web. Male may have white lines on sides of abdomen.</td>
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<tr>
<td><strong>Comb-Footed Spider</strong>&lt;br&gt; Stenodactylus borealis&lt;br&gt; Family Theridiidae</td>
<td>Web a rather loose, open, well-defined platform, held by threads running to supports above and below the platform. In some cavities these supports may extend in almost any direction, giving the platform reasonable stability that is not continuous, as in Tegenaria. Female to over 3/4 inch; male slightly smaller, Back orange-brown, covered with short, stiff hairs. Abdomen chocolate-brown. Light median band on abdomen extends to form lateral band at forepart of the abdomen. Legs hairy and brown, often with faint dark rings.</td>
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**ECOLOGY**

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<td>Larger webs usually domains of females. Males may wander away on own or build smaller webs for catching food. Old webs may be over 1 foot in diameter, are sensitive to disturbances and warn adult in retreat of danger or trapped prey. Finely looped radii are lacy.</td>
<td>Of no recognized major economic importance to man or to his stock or crops, but may destroy many insects of potential danger to man's economy. May adapt to artificial, wooden nest boxes in winter. Not normally aggressive subjects for study on which little information has been published.</td>
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<tr>
<td>Webs found in and around holes in bark, rocks, weathered wood, and even under stones in fields. Females have been observed to remove exposed part of web in early July, then to lay about 13 eggs, which all hatch simultaneously and are enclosed in special egg sac, within retreat.</td>
<td>Probably of little direct economic importance to man, but there are few more interesting subjects for study than the manner in which this animal shakes its triangular web to entrap a meal, suddenly lengthening or shortening the handle of the prong that supports the crossbars of the web.</td>
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<tr>
<td>Eggs deposited in flat, oval, silk sac close to bark of twig. Sac is about 1/4 inch long, and according to Comstock appears under the microscope like dirty white silk crocheted with black silk. Camouflaging dirt makes the egg sac most difficult to find unless it has been deposited in vial by a captive female.</td>
<td>Of no great economic importance, but probably does serve as destroyer of flies that may seek secluded spots in which to winter. Not normally aggressive, and apparently is harmless to man and to man's domestic animals. Webs in cellars may be an annoyance.</td>
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<tr>
<td>Egg cocoon transparent or straw-colored, with eggs visible. Cocoon with longest diameter under 1/2 that of body of female, which carries it about on web until young are freed. Adult female is excepted under close examination. Young shift for themselves after being hatched.</td>
<td>Valuable as destructor of insect enemies of such field plants as grains. Of no danger to man. Most fascinating subject is its almost any time of year, but particularly from May through to winter. If food is available, is good subject for laboratory study.</td>
</tr>
<tr>
<td>Webs found most commonly in grass with a sparse mass of &quot;trip threads&quot; above platform. Threads upset flying insects which are then captured. Eggs, which hatch in winter, are in irregular flat silk sacs under rubbish, usually protected only by female.</td>
<td>An essentially domestic species living on insects and other animal matter that becomes trapped in web. It is unpleasant looking and may mean household uncleanness or neglect, but does not harm man, and may destroy insect pests. Provides fine subject for study.</td>
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<tr>
<td>Males and females live in unusual harmony on same web during the three months of the breeding season. Eggs are laid in oval, silken egg sacs, which sometimes remain suspended under the platform for a number of years. Adults may live two or more years, and be active at most times.</td>
<td>Some relatives of this spider, including genus Dolomedes, which may live on, in, and near water, are reported to eat small fishes and aquatic insects. This can certainly not cause great injury to fish populations, and spiders themselves may be food for larger fishes.</td>
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**Silken egg cocoon in is two halves, and is carried in special structures beneath the female's body until just before the young emerge. Then female builds huge silken web over top of some weed or other object, and in the web places the egg sac, which eventually opens to free the young.**

**In June or July, female makes 3-to-4½ inch cocoons, each containing to 300 eggs that hatch into spiderlings. These feed on each other within the cocoon. Young may mature and breed by autumn, and the females may live through winter. Female commonly eats mate, giving name "black widow."**

**Sexes unusually alike in size and coloration. Males said to be able to produce high-pitched sound by use of stridulating organs. The purpose of this sound is not yet understood. In general, the animal resembles a short-legged house spider. Nest somewhat similar.**

**A retiring species, that attacks only in self-defense. There is no record of their being carried into the nests of other animals. Occur in healthy adult human. Common habitat is among stones or under rubbish and logs, where spiders may readily bite a hand thrust in to move the cover. Known in all the states but Maine, Alaska, and Hawaii.**

**Pain caused by bite is great and may cause paralysis of bowels. Ligatures properly and promptly applied may prevent spread of infection, and weak solution of ammonia and carbonate of potash may be applied with good results. Temperature of victim may be high for 3 days.**

**Not conspicuous, as it lives in crevices and corners under some cover of the nest or platform. This species ranges through the northern half of United States. Two other species are found in western part of the country. One, the commonest, is found in Canada.**

**Probably of minor importance to man and his interests, but it may destroy some harmful insects. The webs may help in the construction of some birds' nests, while the spiders themselves probably enter into the diet of a variety of birds and other animals.**
<table>
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<tr>
<th><strong>WEB</strong></th>
<th><strong>DESCRIPTION</strong></th>
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| **HOUSE SPIDER**  
*Theridion tepidarium*  
Family Theridiidae | Web of loosely integrated threads apparently built with no established pattern. It is usually located under some shelter from rain—most commonly in a barn or house—often in comparatively dark upper angles of rooms, doorways, or window frames. Easiest to discover of all webs. |
| **Golden-Silk Spider**  
*Nephila chopes*  
Family Araneidae | Inside a basic up to 4-foot square of heavy lines there may be secondary inner lines across corners. Inside this is a series of heavy, radial, non-sticky lines. In the center is a spiral of sticky lines with a hub, surrounded by a narrow spiral of sticky lines, then by a free circle, with bigger outside spiral. |
| **Arrow-Headed Micrathena**  
*Micrathena sagittata*  
Family Araneidae | Web to 1 foot or more across. Primary and secondary foundation lines support the many radii that extend to central circle, which is free of radii. Free hub may be conspicuous, and 2 or 3 may be controlled in width of the space by the spider's loosening or shortening the stabilimentum. The spiral is sticky. |
| **Cyclosa**  
*Cyclosa conica*  
Family Araneidae | Normally a frame of heavy silk threads is strung vertically between two or more supports. Within this relatively rigid frame many radial threads are strung unusually close together, and in the center of this structure is a strong close spiral surrounded first by a free area, and then by a large, close spiral. |
| **Zygiella**  
*Zygiella montana*  
Family Araneidae | Web a modification of typical orb web, in which spiral is absent between two radii. Hub area is surrounded by narrow open area. From hub to the foundation lines a strong thread extends through area where spiral is missing. Here spider retreats to open-ended silken tube, and receives signals from prey. |
| **Marbled Spider**  
*Araneus marmoratus*  
Family Araneidae | Web basically like that of Zygiella, but in place of a sector free of sticky spiral threads, it is continuous. Has a netted hub surrounded by narrow spiral area around which is narrow free area. Around this, in turn, is an extensive spiral and strong threads leading from the hub to spider's remote retreat. |
| **Long-Jawed Orb-Weaver**  
*Tetragnatha elongata*  
Family Tetragnathidae | Web a relatively simple orb web with few rays, no retreat, and no stabilizer. Hub is open, without radii, and occupied by spider. Surrounding hub is a narrow spiraled area, which is surrounded by a spiral-free area. This, in turn, is surrounded by a broad spiraled area that extends out to foundation lines. |
| **Bowl and Dolly Spider**  
*Frontinella pyramidata*  
Family Linyphiidae | Web a basic horizontal platform generously supported from a number of directions. Over this is a shallow, clearly defined bowl of silk supported above by threads leading irregularly to strong, main horizontal lines that extend to good supports. The maze of threads above bowl upsets prey as it flies past. |
| **Filmy Dome Spider**  
*Linyphia marginata*  
Family Linyphiidae | Web so delicate that it may be passed up easily under most circumstances. It is best seen against a dark background. A platform consisting of a maze of threads has an inverted bowl or dome suspended over its center. Dome's lower opening may be five or more inches across. Dome is of porous net. |
<p>| <strong>Female body 3/4 inch long. Male body is more slender, to 1/6 inch long. Legs are nearly 5 times the length of the body. Highly variable in color pattern, but many have dark chestnut chevrons on both the top and underside of the abdomen. Appearance is generally dirty and dusty.</strong> | |
| <strong>Female to over 4/5 inch long. Back dark brown; abdomen olive with paired white and yellow spots and line light on the anterior end. Legs with conspicuous hairy tufts at 2 joints. Male about 1/3 length of female. Abdomen 2 1/2 to 3 times as long as it is broad. Third pair of legs is shortest.</strong> | |
| <strong>Body of female to over 1/3 inch long; of male, to 1/5 inch. Female body obscurely arrow-shaped, with yellow, black, and red areas. Legs usually very little longer than the body. Male with narrow body, that is not arrow-shaped, with the abdomen slenderer than female's and widening slightly to the rear.</strong> | |
| <strong>Female body is to 1/3 inch long and male body to 1/6 inch. There is a conspicuous tubercle on back of the abdomen, and eyes are on prominent tubercles. Size of tubercles varies greatly. Tubercles reduced in males, and most prominent in mature females, Color gray and white to black and white.</strong> | |
| <strong>Female to just over 3/4 inch long; male to just under 3/4 inch. Abdomen yellow to brown above with black-bordered conspicuous design. Front part of back with narrow black margin around yellowish area. Usually elaborate design is visible on exposed upper surface of spider's body.</strong> | |
| <strong>Female to 3/5 inch long; male to 2/5 inch. Abdomen of female yellow with darker markings varying from brown to purple, with dark and light areas of varying intensity. Front of abdomen, is yellow with darker lines along sides and middle. Legs of both sexes rather stout and banded.</strong> | |
| <strong>Length of female, exclusive of jaws, to under 2/5 inch; male slightly smaller. Jaws of male more developed than those of female. Abdomens of some females, particularly in related species, may be swollen at forward section. Red-brown abdomen is silvery with various brown markings.</strong> | |
| <strong>Female is 1/6 inch long—only minute- ly larger than the male. Carapace is an even brownish color. Abdomens marked in light and dark coarse pattern, conspicuous because of its bold design. But for the interesting web, the spider might remain inconspicuous.</strong> | |
| <strong>Female to 1/5 inch long and male to 1/6 inch long. Carapace is dark brown with a white border. Abdomen concealed with characteristic brown pattern against pale yellow background. Lateral stripes on abdomen are inconspicuous in the male than in the female.</strong> | |</p>
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<td>Males court females, and are eaten if unsuccessful. As many as 200 eggs laid in silken spheres hung in web 6-8 weeks after mating. Spiderlings hatch in one week and feed on each other through 4 months, then leave cocoon to spend period on web of adult. Female may produce 9 cocoons in one season.</td>
<td>One mating may fertilize eggs for number of cocoons. Young may feed on scraps in adult's web after leaving cocoon. Web often placed in open over entrance to a dark area. Sometimes web is denser over one area, increasing protection for occupant. Ranges through United States.</td>
<td>Ability to adapt itself has made this species almost world-wide in its distribution. Animals are of no direct harm to man, and may destroy flies and mos-quofection of the orb webs. Perfection wasps and birds. Webs used as adhesives by some birds in nest building.</td>
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<tr>
<td>Male lacks leg tufts. Male lives on the side of web opposite that occupied by female. Adult males do not build their own webs. Some species lay eggs in paper, threads from wood, and cocoon and finally suspended in vegetation. Cannibalsitic young hatch in mid-winter.</td>
<td>This species is found commonly in deep woods where there is little wind. Sticky spiral threads are yellow. Others are white. Sticky threads may pull radial threads out of line, and may be bounded by a number of non-sticky spiral threads that permit free movement of the builder.</td>
<td>Ranges from Florida west to California, with related species extending range. Parts of thread might be strong enough to be used in making cloth, but such as us would not be recommendable. Radial lines are exceedingly strong, as are the bordering foundation lines. Webs may be repaired.</td>
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<td>There is no free zone in the web area composed of the sticky spirals. Adult spider may hang in free area at the hub. There is no retreat zone such as is found in many webs. Stabilizing structure is relatively small. Little literature on reproduction in this species.</td>
<td>Species most frequently found in almost upright web suspended from stable vegetation in woods. <em>M. sagitata</em> ranges through all states, east of Oklahoma and Nebraska, with <em>M. gracilis</em> extending range to all states east of the Rockies. When in center of web, spider resembles borerly.</td>
<td>Of no major economic importance and not so well known as it should be. Almost any amateur naturalist could, if opportunity presented itself, make some original observations and experimentations that would add to our scientific knowledge of this interesting species.</td>
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<tr>
<td>Two stabilizing structures extend across central area, permitting tightening and loosening of the web. Here spider may rest, or no retreat area or off web. Spider itself closely resembles a piece of trash, and so is not easily noticed. Young hatch in egg sac.</td>
<td>Spider may shake the whole web, which possibly frightens away pre-decenced visitors. This is done while the spider hangs to the stabilimentum, which extends above and below the central hub. Range throughout the entire United States with the exception of Alaska and Hawaii.</td>
<td>Of no recognized possible economic importance, but must be admired for the beautiful coloration in the egg sacs. At night, webs may be repaired successfully if it is damaged.</td>
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<tr>
<td>Center of orb is made of net itself instead of being a spiral. This center is supported, silk balls are not removed away from the web.</td>
<td>In a close relative, the eggs are enclosed in a series of small silken egg sacs that are tenderly cared for by the orb spider hangs to the stabilimentum, which extends above and below the central hub. Range throughout the entire United States.</td>
<td>Of no great economic importance to man and his interests, but of major importance to students of orb webs, and to those interested in the web's ability to do the same thing.</td>
</tr>
<tr>
<td>In closely related species, egg sacs are laid in strawberry-shaped, almost transparent, silk balls that are removed away from the web or attached to some of the main threads. They do not appear to be strong enough to survive winter, and the plants on which they are placed may be easily killed during the winter.</td>
<td>Genus includes many species of great variety in size, pattern, and habit. Re-treats are usually away from the orb web and connected to it by a strong signal card or cords. This species nests in trees, shrubs, or other wooded areas and its range is most of United States.</td>
<td>Of no economic importance, but of interest to students of spider webs because the retreat area is away from the major web. Limits of its foundation lines give animal independence from dangers of life on the web, at the same time allowing remote builder to control its web.</td>
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<td>In males, jaws are longer than the earapsed (the part of back that lies in front of abdomen), and in females are almost as long. Males more slender than females. Silken egg sacs attached to twigs, and sparingly covered with beaded strings of greenish silk.</td>
<td>Webs are commonly found near water, and are frequently stretched over running water. Webs are sometimes stretched horizontally rather than vertically, as is common practice with most orb-webweavers. Many species are known. This one ranges through continental United States.</td>
<td>Of no obvious economic importance, but serves to eliminate some insects in a niche not commonly the responsibility of other spiders. When spider is extended in web it may resemble a bit of fallen twig, but it is alert in presence of potential meal.</td>
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<td>Apparently relatively little is known about the life history of the most commonly found spider. Females of closely related species have been taken with their egg sacs as early as April. Some individuals have been known to regrow limbs they have lost or injured.</td>
<td>This species is placed by some in the genus <em>Linyphiella</em>, by some entomologists. Its webs have been found in pine woods, in tall grasses, and in bushes, usually relatively close to the ground and well protected from weather. Ranges from New England to Florida, west to Arizona and South Dakota.</td>
<td>Little possibility that species has any great economic importance, but its involved and beautiful webs are of interest. In spite of their complicated structure, a bowl that has been destroyed may be completely rebuilt by the spider within a single day's time.</td>
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<tr>
<td>Spiders mature earlier in common and the females may be found on their own diminutive webs by late summer. Adult lies under the dome watching arrival of any insect that falls on it after having been upset by threads strung above. Prey is quickly caught through holes in dome and drawn under for food.</td>
<td>Obviously such a flimsy nest is subject to injury by the elements and by animals, but the spiders are able to make quick repairs or, if necessary, to build a new web.</td>
<td>Spider of no recognized economic importance, but the dome trap is unique and the reverse of the bowl trap made by the bird and dolly spider described earlier. This tabulation. This species is often seen on piles of rock, in underbrush, and near stone walls.</td>
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nature IN THE SCHOOL

In a little-known poem of the eighteenth century, “The Prophecy of Famine,” by Charles Churchill, we read:

“There webs were spread of more than common size,
And half-starved spiders prey’d on half-starved flies.”

We are all familiar with the courteous invitation a spider is supposed to have given to a fly; and in Pope’s “Essay on Man” we find the spider used as an outstanding example of an animal’s sensitivity to its environment.

“The spider’s touch, how exquisitely fine!
Feels at each thread, and lives along the line.”

On the more prosaic level of the classroom, it becomes obvious that the study of spiders and their webs is one that thrusts itself on many a schoolroom, and yet it is one that is usually neglected. The dust-covered, hanging threads of the spiders wave slowly over the heads of bored students who might, with the proper encouragement, make a study of these creatures. The life histories of such spiders was presented in an earlier insert.

Classes that wish to make collections of spider webs for study and reference may find the following suggestions helpful. If a web is sprayed with white shellac, somewhat as charcoal drawings are sprayed in art classes, the webs may become very sticky. If, while the web is in this condition, a black card is pushed broadside against the web, the shellac will leave a white outline on the black card. If this is covered with waxed paper, it can be filed, and become a part of a school collection.

The student should make a particular study of the web of some orb-weaver, and learn to name and identify its parts and their particular uses. He might also make a report of the ways in which spiders protect themselves, either by escaping from their webs or by effectually concealing themselves upon it. To what extent do they seem to rely upon camouflage for protection?

Some spiders among the orb-weavers make threads that men have made into silken cloth. The spiders are fastened into little holders, and the silk from a number of individuals is drawn out and spun into a thread, which in turn may be woven into cloth. The threads of some spiders have also been used as markers in surveying instruments. What other uses for spiders and their webs can you or your classmates think of?

Most spiders can be kept alive and comfortable in bottles, if water is supplied to them on damp blotting paper, cotton, or cloth. They may construct their webs in these bottles right before your eyes, and may repair them if they become damaged.

Dry-cleaning establishments can supply you with the component parts for excellent cages for observing spiders. Use two wire coat hangers. Fasten the hooks together with a piece of string so that the hangers are side-by-side. Twist one hanger so that its long bottom wire is at right angles to that of the second one. Tie these wires firmly at the place they intersect. Fasten a plastic bag over the hangers so that an opening of the bag is around the hooks, and tie it in place. The bag will hang downward, and the crossed hangers will keep it spread open. Fasten the lower end of the bag around the neck of a bottle with a rubber band and let it hang down. If a source of water is in the bottle, it may be reached by the spider; and if waste material collects in the bag, it should drop into the bottle. To feed the spider, fasten bottle containing flies or other insects to the bottom of the bag so that the insects may make their way upward into the bag where the spiders stay.

Locate a large orb-weaver web in a nearby woodland. Catch some fireflies. Toss a few into the web and see if the spiders attack them. Ascertain if the insects’ light scares the spiders away, and if the fireflies seem to give more or less light when attacked by the spiders. Your observations may make it possible for you to locate orb-weaver webs even at night.

Notice how many of your spiders rest in their webs with their backs downward, and how many are able to run along the top on one or more threads. Can you find any that can run along the top of a single thread?

In an appropriate reference book, or in the twenty-second insert of this series, read about the activities of ballooning spiders. If possible, notice them when they are actively producing silk. The silk floats in the air until its upward pull is sufficient to carry the spider away. This method of travel is most effective when the air above the ground is rising, which occurs, for instance, when the air warms up on a summer’s day.

It is instructive to see how these spiders perch on the top of some lawn plant, such as a dandelion. From atop such a perch, they point their abdomens into the air and expel a stream of silk that hardens instantly. A single ejection of silk may not be sufficient to send the spider off on a journey, but after a while the spider may be able to produce more silk, which, added to the first, may accomplish the desired result. In witnessing such a performance, the student will be able to estimate about how much silk can be produced by at least one of the creature’s silk glands. The writer has seen the ballooning operation a number of times, at least once before the watchful eyes of a large class.

On a window sill, or even better on some old, weathered fence rail, find a few jumping spiders. These creatures leap into space in pursuit of their meals, letting out a silken line as they go. When they reach their prey they stop letting out line, crawl back up the line, and eat the quarry. Inside buildings, the line hangs from the ceiling, collects dust, and makes tidy housewives wonder how and why it got there. At first glance, it seems ridiculous that a spider should make a web that does not lead anywhere in particular! Notice how some jumping spiders have huge jaws, while others have jaws that seem more normal in size. The large-jawed spiders are males, and the jaws are used for holding the female—not for help in eating.

It is hoped that this article will foster interest in spiders, and perhaps send the student off on a spider hunt that will furnish both fun and learning. If you fall sick, are sent to jail, or are otherwise incapacitated, some kind of spider may come along to relieve the boredom! Seriously, these animals are always worth observing, and their study will prove both fascinating and profitable.
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Cacophonous Onomatopoeia

This is how one visitor described the island's wildlife chorus. He spoke of a blending of the surf's rumble and swash, the egret's honk, the gator's siss and the ca-lump of the running deer. To some, these are sounds to be cherished, protected, and enjoyed. Conservation is part of our raison d'etre. We have an oceanfront inn. And a marvelous 18-hole golf course. And 8,200 acres of beautifully wooded, carefully controlled retirement and vacation homesties. Ideally, our island is located between Charleston and Savannah. If you are one of the select few who wish to spend the retirement years in unspoiled, natural environment, write and ask us for an illustrated brochure.

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Sappho Skyarotis is 4½. She is so small, so young, so frail, she seems not quite real. If there are plans or hopes in her mind, they are for an end to the hunger pains in her stomach. Sappho's parents lost their household goods, their flock of goats in a tidal wave. Their patch of land is now unstillable because of the ocean salt. The parents often do without a meal in order to nourish Sappho. Such a small, frail life—
Mechanics of Species Survival

Roaches’ hidden egg cases exemplify protective adaptation

Egg case, when it first emerges from female’s body, is white and soft. In a few hours it becomes tan and hardened.

One of the basic observable facts of nature that led Darwin to formulate his theory of natural selection was that the offspring of most species, in the early stages of their existence, greatly outnumber their parents. Despite this tendency to geometrical increase, Darwin noticed that the numbers of a given species actually stay rather constant. From this he correctly reasoned that, since more young are produced than actually survive, there must be competition for survival. This competition is usually referred to as the struggle for existence.

Prolific reproduction, then, is one basic requirement for the continued existence of most species. But just how prolific reproduction, then, is one basic requirement for the continued existence of most species. But just how prolific must a species be in order to survive? During its life span a codfish or a tapeworm, for instance, may produce eggs by the millions. Similarly, a solitary orchid flower may produce millions of seeds. But, clearly, a high reproductive rate is not the only key to survival, since many successful species—including man—have what is in fact a remarkably low rate of reproduction. Evidently the young of such species must be specially adapted to face and outlast the hazards of the struggle, or must somehow be protectively sheltered from them. Mechanisms for protecting offspring and increasing their chances of attaining maturity are commonplace evolutionary acquisitions.
among both animals and plants. It is our purpose here to call attention to such mechanisms as they occur in a well-known, if poorly regarded, insect group—cockroaches.

Remarkable as it may seem, the behavior of cockroaches has only recently come under careful study, despite the fact that for centuries many of their kind have been man’s constant domestic companions, and that these sturdy insects have for years been chosen as subjects in his physiological laboratories. But cockroaches are active primarily at night; for this reason alone some of their most interesting habits have remained almost undetected.

Several years ago, one of us (Evans), while camping one spring night at Highlands Hammock State Park in the central part of Florida, noticed a group of cockroaches engaged in a most peculiar kind of activity. The species was *Eurydactylus floridanus* (Walker), a large reddish-brown roach, native and quite common to the area. All of the individuals were mature, gravid females, each having a fully formed egg case protruding in characteristic fashion from the rear of its abdomen. The roaches were on sandy terrain, and they were digging. As it turned out, each was preparing a small hole into which it then deposited the egg case, covering it with sand and finally smoothing over the surface so as to leave virtually no markings that might betray its activity.

*Eurydactylus,* we have found, does well in the laboratory. During its nocturnal egg-laying it is remarkably oblivious to outside disturbance. This has made it easy for us to study the animal’s behavior at close range in all its fascinating detail. In the laboratory we keep the roaches on sand in glass enclosures that prevent their escape and in which they can be watched and photographed with ease.

The first sign of the impending onset of egg-laying is the appearance of the egg case, which is slowly extruded from the genital chamber of the female. When it first emerges, the egg case is white and soft, but it gradually hardens over a period of several hours and becomes tanned to a dark brown. Egg cases are quite characteristic of roaches, but the number of eggs per case varies in different species. That of *Eurydactylus* holds about twenty eggs, neatly arranged in two parallel rows within the packet.

With the completed egg case projecting from its rear, the roach now actively seeks out a place to begin digging. It ambles about at a leisurely pace, pauses occasionally to “inspect” the ground with its mouthparts, and then resumes wandering once more. Suddenly, it makes its first attempt to dig. The head is brought forward, is pressed into the sand, and is then pulled back abruptly in a rapid stroke that rakes a small heap of sand to the rear. This initial stroke may represent no more than one of the several false starts that the roach usually makes before settling on a definitive site. Once such a final location has been chosen—and we are still quite ignorant as to the specific environmental clues that the roach relies upon in making its choice—the digging proceeds without interruption, at the rate of a stroke every few seconds. Deeper and deeper the hole is carved, until eventually it reaches down about a centimeter below the surface (see photos, above). In dry sand the entire procedure lasts about thirty minutes.

At this point the hole is more or less irregularly funnel-shaped, and does not at all conform to the configuration of the egg case. But the roach remedies this by shifting to a totally new kind of activity. It dribbles saliva onto the sand in the hole, and with the mouthparts picks up a few grains at a time, removing them from one place and pressing them into another, until finally the hole is molded into a narrow, elongate trough, shaped quite precisely to hold the egg case. The molding of this trough is not a rapid procedure: it may take the roach up to an hour to complete the job. It is interesting to note that the width of the head is about the same as the width of the egg case, suggesting that the head itself might provide the gauge on which the roach relies while shaping the hole.

Now comes the main event—the laying of the egg case. This act is simple—almost anti-climactic—and is completed within seconds. The roach lifts its head out of the

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Roach straddles pit, arches its body upward, and slides case into hole by bending tip of abdomen forward and down.

When completely covered, case is further concealed by a leveling and smoothing over of the entire excavated area.

The egg case is now ready to be covered. Using its mouthparts, the roach picks up sand grains from the margins of the hole, thoroughly moistens them with saliva, and then sticks them onto the egg case. The entire exposed surface of the egg case is roofed in this way with a dense, marked layer of sand, and completely disappears.

The final operation is a general smoothing over of the entire region of activity. Again using its mouthparts, the roach simply picks up sand from one place and deposits it in another, eventually leveling out all major irregularities. It spends considerable time—often more than an hour—at this operation. The female’s job is now completed, and she simply wanders off. Her major concern, for at least a brief period of time, will be the search for food. But within a few days—usually about eight—a new egg case will have matured in her body, and once more she will bury it and conceal it in the same elaborate way.

One of the remarkable things about this egg-laying behavior is its adaptability to different environments. When we collected Eurycoticus in Florida, we noticed that one of the habitats in which it was most commonly found was dead, decaying logs. Within these logs, the roaches scurry about by the dozens, living in an internal labyrinth. We also found egg cases in these logs. But, instead of lying freely exposed within the passages, they were always hidden from view under small piles of shredded wood. We have since seen how Eurycoticus lays its egg case in this type of habitat. It first carves a hole by chewing on the
wood, using its powerful mandibles to tear away small pieces, one at a time. It then deposits the egg case in the carved-out depression and covers it with small wood shreds that are glued to the surface with saliva. Finally, the entire site is camouflaged with a loose cover of larger pieces of wood taken from the surroundings.

We must now ask ourselves about the function of this behavior. The first thing that comes to mind, obviously, is protection. But protection from what? Oddly, one of the main natural enemies may be *Eurycotis* itself. When we kept roaches in aluminum cages, we saw that many of their egg cases—which were now exposed conspicuously on the bottom of the cage—were eagerly devoured by the roaches, even when a surplus of other food was available to them. This kind of cannibalism could be almost completely prevented by transferring the roaches to sand or dead wood in which their egg cases could be buried. We say "almost completely," because even under these conditions, and especially when overcrowded, roaches at times chew away at each other's egg cases while these are protruding from the genital chamber.

But roaches are not their own sole enemies. Ants, carabid beetles, and small rodents, to mention only a few, are each in their own ways potent menaces in the habitats frequented by *Eurycotis*. Burying the egg cases must help reduce the toll that would otherwise be taken by such predators. Then there are the egg parasites. Tiny wasps, for instance, lay their own eggs in roach egg cases, and the larvae undergo their entire development in them. It would be interesting to experiment with such wasps to determine if, when given a choice between exposed and concealed egg cases, the wasps are unable to locate the ones that have been buried.

Finally, there is the possibility that the buried egg cases are better protected against water loss. One might think offhand that the hard shell of the egg case is in itself an adequate shield against desiccation, but this is not so; the egg case that is exposed to the air loses water quite rapidly at continuing low humidities.

After working with *Eurycotis*, it occurred to us that it might be worth while investigating some other species of roaches. We wanted to know, first of all, how widespread this burying habit is and how it varies from one species to another. One most interesting possibility was that by studying the egg-laying on a comparative basis—including for study both generalized and more advanced species—one might be able to piece together the sequence of events that spelled the evolution of this behavior.

We have now worked on more than twenty species from many areas of the world, including representatives of most known families. Our hopes are being realized. Not only is the burying habit rather widespread, but it is also variable. Some of this variability is interesting in itself, even without going into the detailed evolutionary implications. For instance, some roaches dig with their forelegs rather than with the head, others use both head and forelegs. Some completely omit shaping the hole with wet sand, and simply drop the egg case into the unmolder pit. One common native species, *Parcoblatta virginica* (Brunner), constructs an oblique tunnel instead of the usual open hole. Even the very act of laying is subject to variation. Some, like *Eurycotis*, lay the egg case from above while straddling the hole; others turn round to lay, sliding the egg case into place by backing into the pit. There are even a few species that simply drop their egg cases or glue them on an exposed surface, constructing no shelter whatever for their protection.

One should mention that there are some cockroaches that never even lay their egg cases. As with the mammals among the vertebrates, they incubate the developing eggs within their own bodies. When the young are born (right), they are free-living, miniature versions of the adults.
Part II

GIVAMAN

POMA DE AYALA

The post-Conquest chronicle of the Inca State's rise and fall

By John V. Murra

THE INCA STATE of highland South America had been spreading beyond the Cuzco area for less than a century by 1532, when the European invasion began. That the Incas' political and military feats were achieved so quickly seems incredible. From northernmost Ecuador to Chile and Argentina, millions of people and dozens of ethnic groups in mountain, tropic, and desert environments had been defeated and incorporated into the Inca system between 1438 and 1525.

Thus, Inca rule was alien and recent to most subject peoples. But, as we have seen, this was not the first true state structure in the Andes. Guaman Poma de Ayala had argued indignantly against the notion spread by the Inca that they were the civilization in the Andes and the rest to bring order out of barbarism. Although in his 1,200-page letter to the King of Spain Poma was eager to defend all Andean social systems against European libel and destruction, he did not hesitate to distinguish the narrow Incaic from much earlier institutions and accomplishments. Such awareness is unusual in sources used for Inca studies, and it makes Poma's work doubly valuable.

In the four-stage evolution of Andean culture and statecraft he presents in his Nueva Corónica y Buen Gobierno, Poma had to face the fact that after "thousands of years" of benevolent rule by "legitimate dynasties," there came a power a man, Manco Capac, who "had no town or country, nor fields; no fortress, no caste, nor ancient kin... and everything else they say and picture about the said Incas is a hoax." Poma deals only tangentially with the reasons for the defeat of earlier rulers. They ended, Poma says, and the reason for their downfall, he hints, lay in the personality of Manco's mother, Mama Huaco. She was "a great idolator and witch who talked to the devils in hell... and with this she deceived the Indians of Cuzco... and so she was obeyed and served and called queen..."

Poma's version of Inca state mythology is not very different from that recorded by other contemporary chroniclers. Since there was no primogeniture, there were frequent civil wars and periods when several royal sons claimed to be king at the same time. Poma accepts a long count of the early kings and claims that the dynasty lasted some 1,600 years, although modern research indicates that even 300 years would probably be too long to allow for the consolidation of Inca rule in southern Peru, and its later expansion. But then, like most sixteenth-century Andeans, Poma was not very interested in exact dating.

Of all Inca history, the last century before 1532 was the most fascinating period. It was too recent to allow much manipulation by royal myth-makers: too many eyewitnesses of crucial events were still alive. Also, it was a period of rapid territorial expansion accompanied by many administrative, economic, and religious transformations. The personality that was associated most prominently with the expansion and internal reform was the ninth Inca King, Pachakuti, whose name means "cataclysm." Poma is not too reverent about his career: he explains the name by saying "there was much death in the time of this Inca and hunger and thirst and illness and God's punishment so that it did not rain for seven years and some say ten years and there were storms and the time was for weeping and burying the dead; and thus the said Inca was called Pachakuti..." 

PACHAKUTI began to reign while his father, Viracocha, was still alive. In fact, Viracocha had already selected another son, Inca, as his successor. However, when Cuzco was besieged by the neighboring Chanca, Pachakuti organized resistance, saved the city with alleged supernatural help, and eliminated his half-brother from the succession. Poma describes him "shooting at the enemy with his sling with a golden stone in it in his right hand and he defended himself with a shield on his left... he was a great eater and he drank a lot, a friend of wars and he was always victorious... he ruled all the way to Chile." He was the first Inca King to venture to the coastal zones, which produced much maize and cotton. Their inhabitants were relatively easy to defeat since their irrigation systems began in the highlands—he who controlled their sluice gates controlled them.

Pachakuti was apparently the first King to marry his own sister, Mama Anahtaraque. Traditional explanations
**PACHACUTICHING**

Pachakuti, the ninth Inca, is portrayed holding a sling and his shield. He was closely associated with expansion and internal reforms of Inca realm.

**TOPAIINGA IV**

King Topa, Pachakuti's son, extended Inca sphere to north highlands and to the coast. He undertook administrative reforms that consolidated Inca rule.

**CHIMBO CAUA**

Chimbo Caua, the fifth Queen, is shown having a heart seizure. Poma states she had three attacks a day, during which “she shouted and pulled her hair.”

**SEVENTH QUEEN**

Seventh Queen was described by author as “friend of raising little birds and monkeys...” She also liked men, he says, “but the women not very much.”
of royal incest at the Inca court refer to the majesty and high status of the king, which allegedly made any woman other than the king’s sister inadequate as a potential queen. Recent research by Mrs. Maria R. de Diez-Canseco, a Peruvian historian, has suggested a new explanation: royal incest was an attempt to eliminate quarrels over succession by reducing the number of eligible princes.

Another device to reduce succession squabbles was to associate one of the princes with the royal rule while his father was still alive. Pachakuti did not originate the custom, but because of the recency of his reign we have fuller data about his search for a worthy successor. The first heir he picked was Amaru Yupanqui, who took part in the Chilean campaigns. This nomination was withdrawn some years later, since Pachakuti thought the heir was not sufficiently “war-loving.” The next one, Topa, who did much to extend the Inca realm, was a “greatest man of war.” Poma lists many provinces Topa annexed, then claims “he died in Cuzco two hundred years old, he died of sheer old age, eating and sleeping, he never felt death.”

According to Poma, it was Topa, not Pachakuti, who undertook the administrative reforms that consolidated Inca rule. It was Topa who “began to order that they build all the royal roads and bridges and he placed messengers and roadside way stations . . . and he ordered that all the districts be delimited and markers be placed on pastures and fields and hillsides and he built towns and he honored the lords and he ordered that the laws be obeyed and made new laws and he built up his own estate and that of his kin and warehouses, all with great order. . . .”

Topa’s wife was Mama Oclo, his sister, whom Poma describes as “very terrifying and beautiful . . . with a small face, gay at heart and calm, very jealous of her husband . . . They say her husband had 150 bastard sons.”

Despite the several devices to insure peaceful succession, King Topa had to face the rebellion of one of his brothers, who had many followers among the royal lineages and the clergy of the Sun. In addition, the brother, while acting as a state official, “hid” some of the people he was supposed to enumerate in a census by not reporting them on the knot strings (quipu) of population. He apparently hoped to use them as the nucleus of an anti-Topa army. The plot was revealed and the rebels with all their lineage were killed. Then King Topa began to kill the villagers left out of the census. At that point, Mama Oclo intervened and urged him to stop the killing. The Queen suggested that the survivors be used “in the service of the royal llamas, fields and shrines.” Topa agreed, but insisted that these “rebels” should never again be counted in the census, and should devote full time to the king’s estates. These retainers, known as yanacona, were a new, apparently unprecedented, group in Inca society. They were no longer peasants, who owed only a portion of their energy to the state but otherwise lived in traditional ways. Their removal from their homeland and their full-time duties to the king have led some scholars to classify them as slaves and to speculate that the Inca system was tending to become a slave society at the time of the European invasion, but this needs further study.

The next recorded King was a child when Topa died, and his official name indicates this: on becoming King he took the name of Huayna Capac, “Powerful Youth.” He was the last Inca King to die an independent monarch.
before the European invasion began, but even in his time Francisco Pizarro's ships were prowling Ecuador's coast.

The fundamental changes occurring in the Inca social and economic system continued as it expanded. The kingdom grew so large that Huayna Capac began building a second capital, Tomebamba, in the northern territories he had conquered. This is the bland, official version, but there must be other reasons, too. For example, the inhabitants of the newly incorporated territory, the Cañari, were promoted to be personal bodyguards of the king, to the dismay of the royal kinfolk who had always had this privilege. The author hints of serious factional disputes between the royal lineages. Also, since each king had scores of sons, the royal lineages had grown very large and their pretensions and privileges created tension. All this erupted when Huayna Capac died: the usual succession squabble became a civil war coinciding with Pizarro's invasion.

At various places in his chronicle, Guaman Poma returns to this question: why was the Inca state so easily overthrown by a few hundred Europeans? This leads him to recount the war between the royal contenders, Huascar and Atahualpa. "So much disension and fighting and this was the cause of death for so many lords and captains and poor Indians and the destruction of all the wealth... and while all this rioting went on the Spaniards dashed out of Castile to this kingdom and the Indians did not defend themselves like those of Chile..." Some of his explanations for this lack of a defense are supernatural: when Huayna Capac's mummified body was brought to Cuzco "there was much weeping and crying... and what the devils told the new King as a message from his Inca ancestors was that men were due to come called Viracochas... And later the Christians arrived,..."

But elsewhere Poma emphasizes the unheard-of tactics of the invaders, their use of horses and armor: "all his people were scared, aved and each one began to run because they had never seen such a large animal and some men on top of them." Poma also observed that perhaps the character of Huayna Capac's heir, Huascar, had something to do with it: "from childhood on, the said Huascar was very proud and stingy and badly inclined. He would have his captains killed and so they ran from him. He never wanted to be generous with his captains and soldiers. He lost through pride his whole kingdom..."

Faced with the need to organize a single state out of dozens of tribal units and confederacies, the Inca developed a double system of administration. The local gentry were left in office if they accepted Inca rule, while "federal" officials from Cuzco acted as inspectors, provincial governors, and policy-makers for the kingdom.

To leave local affairs in the hands of traditional ethnic leaders was a sound principle of colonial rule. The Inca used the method consistently: local shrines were left undisturbed, as were the gentry: local levies of people for the army or public works were sent where needed, led by their traditional authorities. In battle, they fought with their customary weapons. In Poma's pictures of war the ethnic groups are readily recognizable by their clothes, hair style, and armament. When King Huayna Capac went off to conquer the north, the job of carrying his fighting litter was entrusted to the Sora and Lucana, whose headresses Poma draws differently from those of the Callahuas, who carried the King's litter in peacetime.

Poma is an important source in our effort to determine which jobs in the bureaucracy were left to the local gentry and which were given to Inca descendants. Poma tells of a local official called the suyuyoc, in charge of suyus—tasks to be undertaken in turn by the various lineages and village groups in a valley (the word suyu also has other meanings). A suyuyoc "was to administer the community's [wealth] and that of the [local] gods, and of all kinds of fields, food and fruit, cloth and llamas, and mines as long as they belonged to the community, and of all the sacrifices..." Such provincial administrators were sons of local leaders, but also "they must have ability and be diligent and fit for the job"—here, too, there was no automatic succession to the office. The young of the gentry were "given these jobs so they would learn their skills and how to keep accounts and to manage so they could succeed on the death of their fathers and would know what it was to govern the land." Such ethnic leaders can be distinguished readily from Inca officials in Poma's drawings, since they do not wear the distinctive, royal earplugs.

The contrast is most obvious in the drawing of the royal council that aided the king in governing the Inca state. Since this body was abolished soon after the European invasion we know almost nothing of its composition or functions. Some sources give the impression that its members had to be royal kin, but Poma's illustration contradicts this: the three front figures are all royal princes with distended earlobes, but behind them is one of the author's relatives, with a horseshoe-shaped frontal ornament, and
Inca army, with slings and shields, battles barefoot warriors of Ecuador.

Prince Urco, son of Topa, had to move rock from Cuzco to Huanuco.

State messenger blows conch horn to warn next runner of his arrival.

Treasurer, kin of author, holds a quipu. At left is version of abacus.

Boundary-setters, officials of crown, erect landmarkers in Topa's reign.

Inca official, from the Acoc lineage, supervised bridges throughout land.

Selected maidens, the aklyyn, lived in seclusion; spun, wove for crown.
behind him is the feather headdress of a man from the montaña forests of the Amazon. According to Poma, only four councilors were of royal descent; four more "were great lords from the north." Another four allegedly came from the south, and two each from east and west.

Today there is no way of checking Poma's information, which may well be erroneous in its details, since he wrote long after the council had ceased to function. Still, it is interesting to note how culturally authentic he is, even in his exaggerations: the members of the council are in multiples of four, favorite and magic number of the Incas. Even if the four regions were represented on the council by royal and not local administrators, the principle of such four-directional representation is probably reported accurately. Besides the four directions, the four royal princes also represented the fifth and sixth cardinal points in Andean thinking—up and down.

Below the royal council in Cuzco were a variety of officials responsible for the management and expansion of the kingdom. Most top generals were immediate relatives of the king. The opportunity of rising in the status system by military skill is suggested by other writers, but Poma was too wedded to the notion that hierarchical privileges were respected in the good old Inca days as opposed to their neglect by the Europeans. "They did not elect poor men . . . for leadership because royal highness and majesty cannot communicate with sons of peasants and if the lords were of low birth, the majesty of the Inca would be less valued." Elsewhere Poma is careful to indicate that no one was poor, but in discussing the state he is too eager to show how his European reader the orderliness of Andean social structure and its respect for inherited rank to admit the evident opportunity for upward social mobility provided by the many wars the Inca waged.

The major item of state revenue, which made possible the wars, the lavish court, and the administration, was the yield from state fields in various parts of the kingdom.

These lands were worked by the local peasantry and produced revenues that were stored in state warehouses until they were needed. Aside from labor on royal lands, the peasants "paid no tribute to the Inca or the queen, nor to the lords or any other person but they gave Indians service and women in this kingdom . . . " Peasant energy rather than products of the Indians' household economy thus formed the basis of the Inca state budget.

How the public domain was established—by alienating peasant lands or by expanding terraced or irrigate areas—is not stressed in Poma's pages. He accepts the state's myth that given constant quarrels between various ethnic groups over fields, pastures, and waters, the Incas had to intervene and delimit everybody's holdings to bring peace. Markers were set up, and an ideology was promulgated that lands left in the hands of the peasant community were hence to be considered a benevolent grant from generous king. This contrasts with Poma's frequent exposure of Cuzco claims of benevolence in other areas.

Although the system of land tenure and personal services to the authorities was little more than an expansion of traditional Andean relationships to include the new power of Cuzco, the Inca's state warehouses were a new element in the Andean landscape. They were much larger than community storehouses, since they were meant to feed large armies and bureaucrats on tour with their retinue. But they were also intended to supplement the ecological production of a given region, which, in a country as broke up as the Andes, is frequently determined by what will grow at a given altitude. "The Incas maintained warehouses called colcas in all provinces and those in the southern high mountains stored dried and frozen potato jerked llama meat and wool, while on the coast they stored full of maize and sweet potatoes and chili peppers, cotto and coloring herbs and coca." The administrators at quipu-keepers of such warehouses were local men, often past the age for military or road-building service. Pon
FEW and willing aklya are hanged by their hair from lif, usual penalty for the transgression they committed.

row one, an ancestor of his, presenting the quipu “books” to a relative of the Inca come to check his accounting.

Poma was inordinately proud of the “order and civilization” of the Inca world as manifested in the census and the accounting it allowed. There were many kinds of tribes, “treasurers,” and quipu-keepers. Some “put down everything that happened in each town . . . all accounts and orderliness. These men had so much skill that through the knot-strings they knew so much that one would think it was in script, with the strings they governed the whole kingdom.” When necessary, the quipus could be carried to the provincial governor or even to Cuzco by the messenger system set up along the roads. A message-carrier would start with the knot-string, “wearing a white feather on his head to shield him from the sun . . . and he carried shell trumpet to warn his partner farther on of his coming. . . . They were to take turns [carrying] and were placed half a league apart so they could move fast. . . . They were sons of loyal chiefs and should not be lazy since they were not meant to stop, day or night, and they ate from the warehouses of the Inca.” Elsewhere Poma suggests “. . . they were to have their lands in the dry places [where they served] and their llamas and everything they needed in the whole kingdom.”

This may be an interesting hint to the changes the Inca system was undergoing: were the messengers becoming a full-time occupational group? To be fed from state warehouses while on state duty was routine Andean practice. But to be granted land at the place of service implies saving one’s ethnic community and shifting away from traditional self-sufficiency and an ethnic definition of one’s condition. We do not know the answer to this question.

It is quite probable that many of the so-called Inca roads, particularly on the coast, were actually pre-Incaic. But here is little doubt that much energy and thought was invested by Inca rulers in maintaining and expanding the road system. “There were six royal roads in Inca times,” says Poma, “which were administered by an Inca governor of the Anta lineage . . . they were measured and delimited and built, each eleven feet wide and on both sides stood stone markers and it went straight ahead . . . and on their sides they built way stations where one could rest and there were messengers and they were [well guarded] and the roads well paved and clean and with stones in the swamps . . . .” Across rivers stretched bridges of rope or sometimes balsa rafts, supervised by an Inca of the Aco lineage.

There is evidence that in the last decades before the European invasion various points of articulation within the Inca system of indirect rule were under considerable strain. While the kingdom was small it was easy to find royal relatives to staff the state council or the administrative corps; in time, the positions to be filled grew so numerous and the number of royal relatives compromised in dynastic disputes became so great, that a new source of reliable administrative personnel had to be found. Men from villages in the area around Cuzco, who were long familiar with Inca ways, were drafted for jobs, each village supplying officials for a particular function. Since the Inca system was a transitional one in which kinship was paramount as a way of creating loyalties, newly recruited officials were inducted or ritually adopted into the Inca kindred. Their ears were pierced and they were allowed to wear the earplugs symbolic of their new rank, even if the shapes and sizes of these plugs differed from the earplugs worn by royalty. “Inca does not always mean king,” says Poma angrily, aware of the fictional nature of assimilated rank, “since Incas are both rich, potters and liars . . . .” Poma says some newly appointed inspectors checked on many crimes and if they did not find them they carried stories and lies to the King [instead . . .].”

The shift from royal nepotism to administrative efficiency can be seen in the army, too. Top generals were royal relatives trained for the post from childhood, but peasants were the bulk of the fighting force. Each outfit served under its traditional leader, armed with traditional weapons. It
is probable that King Huayna Capac had in mind a solution to such military problems when he established the Cañari as royal guards—since they were not of Cuzco ancestry and were but recently incorporated into the realm, Huayna Capac could hope to keep them out of the dynastic quarrels in which royal generals were prominent participants. By giving them land in the Cuzco area, he promoted them to high status and provided them with what in Inca terms was an independent income, yet kept them away from their traditional associations in southern Ecuador. Since the Cañari were full-time soldiers they could be used any time, unlike the peasant conscripts who tended to watch the agricultural calendar and to slip home if they felt their subsistence was threatened by their absence. Despite their high status, the Cañari guards were kept under tight control by the king. In some ways they were comparable to the yana servants of low status, discussed earlier: the Cañari, too, were a basically new group in Inca society. Removed from their homeland, Ecuador, they were made state retainers. Poma had little use for them: “they were rebels, thieves and liars.”

A final glance at emergent groups in Inca society focuses on the aklyá, weaving girls who were kept in “nunneries” according to the Europeans. Like the yana and Cañari, the aklyá were plucked from their ethnic, peasant background, and assigned to professional specialization for the benefit of the state. Also, they were forbidden to marry. While agricultural and military retainers are frequently found throughout the world, the idea of a full-time, female corps of state weavers is peculiarly Andean.

Textiles in the Andes have long been admired for their excellence. We know that for thousands of years before the Incas, garments were a favorite offering to the gods, an important indicator of social status, and the preferred gift between individuals. This made clothing a convenient token in the Incas’ manipulation of people, and in time clothes became one of the main rewards for those serving the state. Soldiers and generals, carriers of the state’s provisions, and pilgrims to the Sun’s shrines expected and felt well rewarded with garments presented to them from the king’s warehouses. Such institutionalized generosity could be displayed only because throughout the kingdom millions of women were weaving annually to replenish the textile stockpile of the Inca state. At some point in Inca history widespread but part-time devotion to weaving was no longer adequate: the full-time aklyá were established and their removal from their families was justified as a “selection” for higher, religiously flavored duties.

Poma’s data on the aklyá are the most detailed available to us. He claims there were twelve categories or stages: “six kinds of virgins of the idols and six other kinds of ordinary virgins.” They differed in status, age, and degree of availability to the attentions of the kings and their captains. As did the European observers, Poma stresses the unlike qualities of these women. He devotes a full page to the punishment of those who seduced an aklyá: for example, hanging of both parties by the hair from a cliff, “where they suffer until they die,” if both had agreed to the transgression. Even if the aklyá were unwillingly seduced or forced, she “received fifty lashes with a rope with a stone at its end, and she ended up half-dead, . . .”

Still, if one checks Poma’s description of the several
kinds of young women lost to the community, the nunlike analogy recedes; "virgins of secondary shrines and idols, called sumac acllap cutiquin ('those who follow the beautiful chosen ones') thirty-five years old, these spun and wove the clothes of the shrines, . . ." He also lists "another house of tiny virgins, called uinachicoc aclla ('chosen to make them grow') who entered at the age of four to learn to work, weave, spin . . . and they stayed in this house until they were ten, learning a woman's job . . ." Others were "acllas of the Inca himself, some of them were virgins, some corrupted and concubines of the Inca . . ."

The cruel penalties exacted from molesters of the aclla are matched in Inca law by the punishments that were meted out to other criminals. There were few fines or jails in the Andes. The Inca state, like the peasant community before it, preferred to administer corporal punishment, to which the state added the penalty of wiping out a culprit's entire lineage in cases of "treason" or rebellion.

The most widely publicized state sanctions affected the pretenders defeated in battles of royal succession. "They had drums made of fords who had been rebels and traitors," reports Poma, "drums made of their whole body dressed in the clothes of their rank, they called these drums runa tinya, human drums . . . and they used the dead man's hand to slap the drum's belly." This also happened during the European invasion when a captain, "son of an ordinary peasant Indian," took advantage of the chaos in the country to kill and make a drum of one of the royal pretenders, a youth of twenty. But the murderer was killed in turn by the Indians "because he had done much other harm . . . and thus ended the life of the poor captain," says Poma, abandoning his hierarchical stance to reveal a sympathy with local men who could act on their anti-Inca feelings.

One form of state punishment deserves particular attention. According to Poma, a person accused of especially heinous crimes was taken to "a cave below ground, very dark where they raise poisonous snakes, pumas and jaguars, bears, foxes, dogs and mountain cats, vultures and owls, frogs and lizards. They had very many of these animals to punish the rogues and delinquents . . . whom they placed so they would be eaten alive. And some were not eaten by a miracle of god and they locked him up for two days . . . and if he escaped from these animals, the Inca ordered that he be taken out and freed without blishment and forgave him and returned him to his honors. . . ." Such ordeal caves existed only in cities; "First, because only large cities require them and second, because the majesty of the Inca was the highest justice and third, with this fear, the country did not dare rise . . . they said nothing."

The Inca state and the royal dynasty were also extremely active in religious matters. While local Andean shrines and cults were allowed to continue, the state church demanded much of the peasantry, for church revenues, like those of the state, consisted of peasant energy—in this case expended on church estates, which were separate from those of the state. King Parachutí, the great transformer of the Andean social order, thought that religion could also play a unifying role in a kingdom that was characterized by extreme cultural and religious diversity. He made a deliberate effort to create a state cult of a Supreme Being, who was also the Creator, known to the Inca as Tézki Wiracocha. The cult was meant to supersede the earlier, local Sun worship on the hill of Cuzco, a large sun temple was erected where a statue of the Sun-Deity. The Sun Temple was a great sanctuary, a temple of the Sun, a temple of the Inca. It was the center of the Inca state, the center of the Inca religion.
prayer to this new deity: "Oh, fundamental Wiraqocha, nearby Wiraqocha, wherever you are in the sky or in the world or at the end of the world, listen to me Creator of the world and of man, wherever you are, listen to me."

Most of Poma's discussion of religion, however, is phrased in terms of the Cuzco ceremonial calendar, which in time became the state cycle of ceremonies and festivals. Thus, the Sun feast took place at the winter solstice, "when they made great sacrifices to the Sun, much gold and silver and pottery and they bury five hundred innocent children . . . alive and upright with their silver and golden vessels and much powdered sea shells and llamas and after the sacrifice they had a great party, they ate and drank at the Sun's expense and they danced in the public plaza." Poma contrasts this holiday with that of the Moon, which was celebrated at the autumn equinox: "of all the planets and stars, the Moon is queen, and wife of the Sun and thus it was the feast of the Moon; women divert themselves most during this month . . . and they treat the men and during this month also the Incas ordered that illness be driven from the towns . . . the men armed as if going to war, discharge their slings, saying in a loud voice: 'Out, illness and epidemic, leave the people and this town, leave us.'"

The bulk of the material quoted and discussed in this article comes from the first third of Poma's letter to the King. At the conclusion of this section, Guamán Poma turns to the world he lived in, colonial Peru eighty years after the European invasion. Here, his text oscillates between an anguished recital of cruelties, abuses, and horrors committed by the invaders and a methodical, if repetitious attempt to devise a "good government" from fragments Inca organization still familiar to Andean Indians in 1616.

Looking to the past, he addressed the European reader, "Look here, Christian, see all the order, good and bad. Now, Christian reader, I have divided it into two pan parts, the bad set aside to be punished, with the good to set God and His Majesty. Look here, Christian reader . . . did not find the Indians to be so greedy of gold and silver nor did I find an Indian to owe a hundred pesos, nor liars, gamblers or idlers or whores, nor do they take this from each other . . . Do not be afraid Christian reader of the idolatry and ancient fights. The Indians were in error as heathen, they missed the true path, just [as] the Spaniards once had idols . . . and the Indians as barbarians gentiles went over their broken idols at the time of invasion. . . . It is you who have it all, disobedient to your father and mother and to the prelates and king and if you deny God, you deny him fully. All this is yours, and you teach it all to the poor Indians . . . it seems to me, Christ, that all of you are damned to hell."

After 309 more pages of angry protest, Guamán Poma finished his book. He hoped the King would see that he would read the many pages of royal questions Poma had anticipated in his fantasies, and that he would consider Poma's answers on how to govern Peru. "I crave the e and souls of the Christians of the world," Poma says, "Look here, Christians of the world, some will weep [on reading this book], some will laugh, others will damn it. Some will entrust me to God, others will come apart from sheer anger but some will want to hold this book and chronicle in their hands to restrain their soul and conscience and hearts. .
The Author's dream of presenting a chronicle to Philip III, King of Spain, was never realized. But the Andean Indian did meet the King in fantasy, in this drawing of himself kneeling before the ruler of the oppressors of his people.
When I was gathering information for my Handbook of Turtles ten years ago, I was struck by how little was known of the sea turtle fauna of the Pacific coast of the Americas. During the decade since that time a good deal has been learned about sea turtles in some areas, but the eastern Pacific has remained neglected territory. Even in Mexico, despite the seasonal immigration of zoologists from the United States, recorded observations are so scant and so rarely supported by good identifications, and specimens in museums are so few, that it has not been possible to tell which kinds of turtles nest on the coast, or even which kinds turn up as strays.

During the summer of 1960 I began to feel so uneasy about this that I set out to see what these neglected territories were like. During August and September I took the hot road south through Sonora and Sinaloa and down into Nayarit, the states of Mexico that make up the eastern shore of the Gulf of California. I turned inward whenever the way looked promising, and managed to reach the following places: Puerto I...
Turtle Problem

By Archie Carr

Frequenters of both the Atlantic and Pacific coastal areas, the Chelonia, as a Caribbean migrant, has stations and a range that are generally known, as map indicates. Those of the Pacific relative, however, have yet to be determined.
Kino Nuevo and the shores of Kino Bay, Guaymas and adjacent beaches, in the State of Sonora; Topolobampo and the shores of Ohuira Bay, Mazatlán, Sábalos, Los Serritos, Teacapan, and Tamboritos, in the State of Sinaloa; San Blas, and Matanchén, in the State of Nayarit. Although there is still a lot to be learned about West Coast turtles, at least I can speak of this fauna with more confidence, and a start has been made in tracing the travels of the local race of *Chelonia*—a handsome color phase called locally by Spanish names that all mean “black” turtle.

During previous short trips to the Mexican Pacific coast, the loose terminology the fishermen used had hindered my questioning the residents about sea turtles. *Caguama*, for instance, is evidently an old Carib name for the loggerhead—a term that in pre-Columbian times spread to the Pacific coast. In southern Mexico and Central America the word is now in general use for the ridley (*Lepidochelys*), North of Acapulco, however, it means simply “sea turtle.” Thus, to ask if the *caguama* occurs in a given place is likely to produce little information on the kinds of turtles that actually live there. Having recognized this before my 1960 trip, I began asking fishermen to describe more precisely the kind of *caguama* they knew, and was able to work out this list of equivalent names:

- *Cerco*, the rarely observed hawksbill (*Eretmochelys*);
- *Galapago*, the leatherback, known as a straggler (*Dermochelys*);
- *Mestiza*, exceptionally light-colored examples of the ridley (*Lepidochelys*) or of the “black” turtle (*Chelonia*), possibly also the loggerhead (*Caretta*), if it occurs in the region;
- *Gofina* (or in places where it alone occurs, simply *caguama*), the ridley (*Lepidochelys*);
- *Caguama prieta* or *tortuga negra*, the “black”—elsewhere, green—turtle (*Chelonia*).

In making this survey, I resorted to all possible means of collecting information. Besides systematically questioning local fishermen and turtle and egg hunters, I walked beaches, searched dumps for turtle shells and bones, visited markets, creeks, and docks where turtles were landed, and cruised 300 miles in offshore waters.

In the 650 miles from Kino to San Blas, including much of the eastern shore of the Gulf of California and the coast south of the mouth of the Gulf, only two kinds of sea turtles, *Lepidochelys* and *Chelonia*, seem to occur regularly. Of the live turtles I saw, and of the shells, bones, nests, track and careases found in markets—total of about 230 animals—all but one were either *Lepidochelys* or *Chelonia*. The exception was a half-grown dead hawksbill that I found on a beach at Kino, two miles north of the village. Nowhere along the coast did I see the leatherback, although the people were acquainted with it as a straggler and at several places referred vaguely to distant leatherback nesting grounds. Although only the one dead hawksbill was seen, it was alleged nearly everywhere that hawksbills came ashore to nest once in a while. It was also said they arrived in few numbers than did ridleys, and favor the same places as the ridley “rockier places”—which presumable meant sections of beach bounded by rocky promontories. I had previously heard this same report at several localities along the Central Pacific coast, particularly in the Gulf of Fonseca in Honduras and El Salvador, I have not been able to corroborate it.

The one sea turtle of which no sign was found, either directly or through verbal reports, was the loggerhead. In some places it seemed possible that the name *mestiza* might apply to a fifth kind that would have had to be *Caretta*, but elsewhere exceptionally light-colored examples of *Chelonia* or *Le...
Green turtle, the *Chelonia* of the Caribbean and Gulf of Mexico, is identified by its sparse dark markings on light ground color that varies from brown to olive. This pair was photographed at Tortuguero, on the coast of Costa Rica.
schedule is strikingly like that on the turtle-grass flats between the Suwanne River mouth and Tarpon Springs Florida, and is what one expects of a colony of young animals, born in some distant place and destined to return there to breed in some future period.

The only known center of growth nestling by Pacific Chelonia in Mexico is considerably farther south—at Maruata Bay, on the coast of the State of Michoacan. This colony has been described by Dr. James Peters in *The Biologist.* It is probably the main breeding assemblage for a great extent of the east Pacific shore—possibly for all that north of Michoacan. The more accurate and articulate informant from Kino to the coast of Nayarit agreed that the main nesting ground of *caguama prieta* or *negra* (*Chelonia*) lay “somewhere to the south.”

That the Maruata Bay assemblage may be unique is also suggested by the attention given it in the account of the seventeenth-century explorer William Dampier and that of his mate, William Funnell, writing in the eighteenth century. I have not yet been able to visit Maruata. Although Dr. Peters sai nothing about the coloration or shape of the shell of the nesting turtles he observed there, it seems possible that they may be the parents of the immature black turtles that turn up as summer residents in the Gulf waters.

Nowhere were there found stages in weight between the approximately 15-pound minimum of the Kino series, and the hatchlings and breeding adults at Maruata Bay. This too, brings to mind the situation in the Caribbean and Gulf of Mexico. Young green turtles weighing 10 to 50 pounds are seasonally common in Florida, while only breeding adults and new hatchlings are found in Costa Rica waters. Nothing is known of the fate of the hatchlings or of the origin of the itinerant Florida population. The parallels with the situation on the Pacific coast suggest that the life cycles of these two colonies involve similar patterns of developmental migration.

Both the immaturity of the black turtles at Kino and the curiously unbalanced sex ratio were duplicate farther south at Topolobampo, where the shells of 115 *Chelonia*, caught near the little islands in spectacular Ohum Bay, were examined. In about a third of these, sex could not be determined in the rest, males made up only 4 or
A.

At Mazatlan, Tamboritos, and Tecapán, no evidence of the occurrence of the black turtle was found, though the ridley was obviously common. The next appearance of _tolonia_ on our trip south was at San Lazaro, where, among numerous shells and bones of ridleys, I found the carapace of a single freakish black turtle. Indently an adolescent male. It was 1½ inches in length, as dark as a no turtle, and peculiar in having five terals—the big scales along either side of the shell—on the left side, and the normal four on the right. Having heard much talk of the _mestiza_ here, I tried the carapace and that of a female ridley to a fisherman who had impressed me as both sensible and familiar with the local turtles, and asked him what they were. The ridley he called _golfina_, and the other, the odd _tolonia_, he said was _prieta_. I asked him what sort of turtle _mestiza_ was. He traced along the shore among ridley chels. chose one a little lighter in for than the rest, and told me that as _mestiza_. When I objected that in _mestiza_ and _sinola mestiza_ seemed to be the name for a color phase of _prieta_, the man admitted that the term is loosely used. It seems probable, then, that along the Mexican coast the term _mestiza_, which means crossbreed, is not restricted to any one kind of turtle; it is simply used for any specimen that looks strange or exceptional.

After going home and meditating on the black turtle, I began to see how naturalizing incomplete the summer's observations were. There was the coast of California—enormous locality I had visited and the one known nesting ground at Maruata Bay. There was also the recurrent talk I had heard of nests of sea turtles round La Paz, which is in the state of Baja California, on the opposite coast of the "Sea of Cortés" from that I had visited. I decided to go back to Mexico to piece out something more of the story.

At Manzanillo, the chief port of Colima, only about fifty miles north of Maruata rookery, fishermen knew the black turtle well, but said they caught it only rarely. The turtle they were bringing to the local market was

**Typical plastron** of Atlantic green turtle, *above*, is clean greenish white.

Plastron of the "black" turtle, *below*, found along Pacific coast of Mexico, is distinguished by blue cast that is caused by deeply placed black pigment.
the ridley. My scratching about local dumps and garbage heaps substantiated the word of local turtle experts that, although prieta is an occasional visitor there, it is much less abundant at all seasons than the ridley, and never nests on nearby beaches.

From Manzanillo I crossed to La Paz. Here the situation proved to be precisely like that at Kino Bay, with black turtles sufficiently common to support a small local fishery, and with the ridley, at least at that season, sparingly represented. The black turtles there graze on beds of algae, and are taken with both harpoons and nets. As at Kino, the colony is made up of young turtles. Of twenty-one that I measured, the range in shell length was from 17 to 32 1/2 inches, with an average of 24 3/4 inches. The largest specimens of both sexes were apparently not quite mature.

When I asked turtle fishermen about nesting grounds, some looked vague and said, "¿Quién sabe?" Others made directionless gestures in the air and said maybe they nest in Sonora or Sinaloa, or in other places in which I was pretty sure they did not.

As on the mainland side of the Gulf, the Baja California turtles are readily distinguishable from Atlantic Chelonia on the basis of color and of the shell shape of the nearly grown female. The head and the forelimbs are much darker—often a nearly solid black. The upper shell is either deep black or heavily blotched with separate sooty markings, while the plastron is clouded with deep-seated pigment that shows blue through the shiny belly scales. I should say that a complete novice in turtle study would be able to separate 93 to 96 per cent of a mixed lot of Chelonia from La Paz and Cedar Key. The confusing ones would be occasional individuals that completely lack the strong pigmentation, and are too small to show the steep shell-sides. It is of interest that on both sides of the Gulf of California these exceptional specimens, which to my eye look like good green turtles, are referred to by some people as mezzas. Whether they are simply variants that turn up among more typically pigmented brothers and sisters, or are waifs brought in by currents from some distant place, only breeding experiments will be able to reveal.

The green turtle of the Pacific coast of the Americas was first described from Guatemala by the nineteenth-century French zoologist Bocourt, who named the new species agassizii in honor of the great American naturalist, Louis Agassiz of Harvard. Bocourt said nothing of his new turtle’s being blacker than usual. Through the past twenty years I have seen several dozen Pacific green turtles along the coasts of Central and South America, and while I had previously observed the steep shell of the young female (1 illustrated it in my Handbook of Turtles), I don’t recall having particularly noticed any such heavily pigmented look as the Mexican turtles have. The limits of the territory occupied by caguama prieta remain to be determined. Eventually, it must also be known whether its curious coloration is hereditary or is produced directly by some factor in the environment—by the diet of algae, for instance. If the trait is inherited, and if the turtles showing it are confined to the upper Pacific coast of Mexico, there is a good probability that someone will give the population a new scientific name.

One of the most interesting aspects of the situation is the way the few known facts seem to fit into a world pattern of sea turtle natural history. So far, only the outlines of the pattern have emerged; but wherever good information is available the indications are that the half-grown Chelonia lives in places distant from both the feeding grounds on which the mature turtles spend most of their lives and the beaches to which the females go at three-year (rarely two-year) intervals to nest. Where baby turtles stay during their first year of life nobody knows; and the travels of all stages are almost wholly hidden.

Meanwhile, the most useful result of the recent observations in Mexico is pinning down the common names. The terms are misused here and there; but not often by the real conocedores, not by the sound old turtle men. Knowing these names clears the way for more profitable sifting of folk zoology for leads that can be used in locating and separating habitats of the Pacific turtles. With this done, we can then trace their migratory routes and stations.
**FAMILY CHELONIIDAE**

*Chelonia*, the Atlantic green turtle, has same facial features as relative, Pacific "black" turtle.

**FAMILY DERMOCHELYIDAE**

*Lepidochelys*, known by Mexicans as *golfina*, *caguama*, or *mestiza*, is the ridley.

*Caretta*, known in English as loggerhead, was only species not found along Pacific coast.

*Dermochelys*, a straggler along Mexican coast, where it is called *galápagos*, is the leatherback in English.
A study of the role of the pineal system in amphibian behavior

By William M. Adkins III

Extensive research into the nature of the pineal system and its functional significance in animal groups, from lamprey to man, is experiencing a new revival. This tiny series of connected outgrowths from the forebrain (diencephalon) has fascinated men ever since Galen. Speculation as to the nature of the pineal system has passed through several stages. Descartes, for example, thought of the system as the “seat of the soul.” Today, the pineal is considered to be tissue of uncertain function.

Recently the pineal system in the lower vertebrates—fish, amphibians, and reptiles—has received particular attention. Certain pineal outgrowths in these animals lie under a layer of translucent skin above the brain, or in or beneath a light-transmitting region of the skull. These apparent specializations for light reception suggest a sensory role with respect to solar radiation.

In 1938, Stebbins and Eakin published their studies of the photoreceptive capacity of this “third eye” in reptiles. When the pineal element was removed or shielded in four species of lizards, striking behavioral and metabolic changes were noted. It was found, among other things, that treated lizards spend a greater amount of time in high-intensity illumination and are also poorer at surviving when deprived of food.

This study applies Stebbins and Eakin’s general techniques with reptiles to the amphibians, instead. Pineal interference was achieved by blocking the influence of light on this system of brain tissues in two species of the Amphibia: the leopard frog Rana pipiens and the southern toad Bufo terrestris.

Several fine studies, notably those of Kelly (1960), have been published on the histological and histochemical features of the pineal system in European amphibians. The most conspicuous element of the system is a small saclike piece of tissue, the stirnorgan, which lies beneath a translucent spot in the skin between the eyes. Studies of this element in Rana pipiens show it to be connected by a stalk that pierces the skull through a minute opening, drawing at right.

Kelly has shown that such stalks enclose a nerve tract connecting the stirnorgan with the remaining pineal tissues in the skull. Pineal function in the leopard frogs was investigated by means of removing the stirnorgan. This was done by cutting out an area of skin, 2 mm. square, in which the stirnorgan was embedded, from each of the frogs. Within a week, the wounded area had healed. As a matter of control, a 2 mm. square area of skin was removed from the right hind legs of other frogs. Such animals were referred to as “sham-operated.”

In southern toads, all pineal elements are evidently positioned within the skull casing, no stirnorgan being present. Any solar radiation that might affect this pineal system would have to penetrate both the skin and the brain casing.

Since surgical removal of any portion of the pineal in the toads might cause damage to the brain, an alternative method of study was devised. Petroleum (as a skin protector) was smeared over the skull between and on the cranial crests. Then a non-drying putty pound was pressed on the skull in a way that no light could enter between this putty shielding and the skin. Application of the putty had no apparent effect on the molting cycle of the shielded toads and, for this reason, no sham-operation was conducted on the control toads.

Rana pipiens were obtained from the kosh, Wisconsin, where they were collected during the fall months and stored in spring-water holding pans. Upon arrival at the laboratory, they were either immediately put into an experimenter’s run or stored in a refrigerator at 10°C until needed. Bufo terrestris were collected from fields in the Melboum, Florida, area during heavy "hurric...
In March of this year, seventeen-year-old William M. Atkins III, of Melbourne, Florida, placed third among 1,000 high school seniors in the Westinghouse Science Talent Search. Part of his prize-winning study is on these pages, Mr. Atkins will use his $5,888 Scholarship to study at Harvard. His paper is followed by a commentary on the work and its importance, written by Dr. Richard G. Zweifel, Associate Curator of Herpetology at the American Museum of Natural History.

In late October and stored until the ne of experimentation,

It is believed that much experimental work on pineal function has failed yield noticeable results because of the experiments’ efforts to maintain uniformity in the environment. In the lower reatitudes, metabolic activity is con- and maintained by movements to id from certain intensities of light and temperature and areas of varying water m. It seemed especially important, erefore, that a wide spectrum of enronmental conditions—to or beyond the upper and lower extremes of toler- be available. Then the effect of meal interference might appear as an ered behavioral pattern.

Using this approach to the problem, indoor environmental gradient cham- r. 3 feet by 6 feet in size, was con- that allowed the leopard frogs to ek three moisture situations (water, ist sand, and dry sand) extending rough three areas of light intensity: ep shade, weak shade, and light shade on page 14). This chamber was built in a controlled-temperature room, where the aperture through the chamber could maintained within 2° C. (Mean air peratures were: 25.2° C. in full light; 1.1° C. in weak shade; and 24.3° C. in ep shade. Mean water temperature was 23.5° C.)

Open-ended cardboard boxes were tised in each lighted area of the sand- runways, providing corners and s with which the frogs could come close contact. Observations were made this thigmotactic behavior, as well as light and soil moisture preferences. total of 494 observations were made 3 normal control, 17 operated, and 10 sham-operated frogs.

A similar, but smaller gradient cham- r. 2 feet by 3 feet in size was used to the behavior of the toads. This chamber cided for four moisture variations— wet, soggy sand, moist sand, and dry nd—traversing a three-dimensional of light and temperature (from 6° C. in the deep-shaded area to 26°C. the fully lighted area). Records were ken of the toads’ preferences for light of soil moisture, and of general skin generation. Both shaded and control ads were studied for 20-day periods in perimental runs accommodating four ds. Four runs were conducted, two of which yielded sufficient data on the ects of shielding on behavior.

Response to Light and Soil Moisture

The behavioral responses of the leap- ard frogs to light and soil moisture were observed by lifting a black drop canvas on an open side of the chamber and recording the position of each frog by scoring each one with the following point systems:

**Light Exposure Index**

<table>
<thead>
<tr>
<th>POINTS</th>
<th>POSITION OF FROG</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Exposed in deep shade</td>
</tr>
<tr>
<td>2</td>
<td>Exposed in weak shade</td>
</tr>
<tr>
<td>3</td>
<td>Exposed in full light</td>
</tr>
</tbody>
</table>

**Water Metabolic Index**

<table>
<thead>
<tr>
<th>POINTS</th>
<th>POSITION OF FROG</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Immersed in water</td>
</tr>
<tr>
<td>2</td>
<td>Resting on moist sand</td>
</tr>
<tr>
<td>3</td>
<td>Resting on dry sand</td>
</tr>
</tbody>
</table>

All data were analyzed on a group ba- sic and treated in two ways. The first 100 observations of light exposure and water metabolic indexes were summed up for each run, so that a simple statistical an- alysis might be applied. The light ex- posure and water metabolísm indexes of normal control and sham-operated frogs were totaled; those of the operated runs were summed up. It was supposed that if frogs have no preference for any light intensity, they will spend equal amounts of time in each light area of the chamber and receive 400 points, as a group, in 200 observations. The control group re- ceived 375 points, deviating by 25 points from the expected 400. The operated group totaled 181 points, deviating by 81 from the 400 expectancy.

Removal of the stigmorgan thus ap- pears to have a significant effect on the preference for light intensity, lead- ing these frogs to spend more time under bright illumination. In comparison, no significant difference appears between the water metabolic indexes of sham- operated and stigmorganectomized frogs.

A computation of the percentage of time spent in all areas of light intensity and soil moisture of the chamber indi- cates that stigmorganectomized frogs make greater use of bright light than the sham-operated frogs.

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point systems was used to study the behavior of the southern toad. The light exposure index considered the characteristic burrowing behavior of the toad:

Light Exposure Index

1. Completely exposed in deep shade, or head protruding from deep-shaded burrow
2. Completely exposed in weak shade, or head protruding from full-lighted burrow
3. Completely exposed in full light

Water Metabolic Index

1. Immersed in water
2. Resting on soggy sand
3. Resting on dry sand

Shielded toads tended toward higher light and temperature intensities and a drier substratum, although no significant differences in the total light exposure or water metabolism points of shielded and control toads were apparent.

Thigmotactic Response

Observations were also made of the percentage of time spent by the leopard frogs in contact with objects and with other frogs and the effect of the stuntor's removal on this thigmotactic response. Operated frogs appeared to spend greater time in "huddles" and close contact with each other than did sham-operated and control toads. No exceptional differences showed up in contacts with inanimate objects.

Pigmentary Responses

Responses of the skin pigmentation to pineal interference could not be easily studied in the frog experimental runs. These responses were recorded for the toads, however, using a three-point system: 1, light; 2, medium; and 3, dark. Pigmentation points received by control and pineal-shielded toads suggest that interference of the pineal induced blanching of skin pigment cells and general paling of the integument.

A different experiment was designed to study the effects of stuntor removal on pigmentation in frogs kept in continuous light or darkness. Four operated and four sham-operated frogs were placed in a lighted aquarium (mean temperature, 23.5°C). Three operated and five sham-operated frogs were placed in an aquarium in a complete dark incubator (mean temperature, 23.5°C). The same three-point system used for the toads was applied to the frogs. Records were taken daily. At 1, 18, and 23 days, mean points received per individual in each group were computed, and differentials between operated and sham-operated frogs estimated.

As expected, frogs in continuous darkness were darker than those in continuous light. In both light and dark groups, the operated frogs were somewhat lighter than sham-operated frogs, although there was a lesser differential in the dark group. In the dark group, the differential consistently decreased with the number of days of exposure; in the light groups, it increased with the number of days. On the basis of these findings, there is strong reason to believe that the stuntor plays a role as a light receptor and a mediator between the external lighting conditions and the pigmentary system of Amphibia.

Sensitivity to the Observer

One of the interesting behavioral patterns observed by Stebbins and Eakin (1953) in parietalotemicolized lizards was their lack of response to the observer at the time of observation. Though no records were made during the four runs on Rana pipiens, casual observations were consistent with those lizards: only those foreign sounds or movements of a high intensity proved scare or activate the indifferent stimulated frogs. Sham-operated frogs were of a more sensitive nature, a
greater care was required to avoid frightening them while the various records were being taken.

Water Metabolic Rates
An interest in the rates of water uptake and water loss through the skin of *Bufo terrestris* brought about a study of these rates in individual toads following pineal shielding. Trends, although not significant, appear to suggest that pineal-shielded toads exhibit a slower rate of water loss and a faster rate of water uptake than usual.

It is interesting to note one occurrence that was observed following pineal interference in *Bufo terrestris*. Pinealed and control toads were divided into two groups, one being placed in continuous light, and the other in continuous darkness. This was a pilot run at long-range pineal-shielding, and a portion of the toads was sacrificed every week for a one-month period. During the latter part of this experiment (with only 1 toads remaining), neglect to refill the aquaria with water produced desiccating conditions for a span of time during which 30 to 40 per cent of the body weight of a toad could be lost. It was found that five of the six pinealed toads had reached the intolerable limit of their water loss and did not survive the evisceration; however, all of the control toads survived and appeared in “good condition.”

Summary
1. Both operated frogs and shielded pads consistently made greater use of high-intensity light, and trends indicate greater use of a greater amount of light.
2. Operated frogs spent a greater percentage of time in thigmotactic response with other frogs. Casually observed also indicated that they are less sensitive and less likely to retreat in response to excessive agitation in the form of movements and sounds by observers.
3. Shielded toads are somewhat lighter in skin pigmentation than are unshielded control toads. In a different experiment with frogs, a paler condition of the skin follows with operated frogs kept in continuous light but not in continuous darkness for 23 days.
4. As in lizards, the pineal system appears to regulate the metabolic activity of amphibians by responding to light and influencing their behavioral patterns. It is believed that normal functioning of the pineal in response to light is necessary for the survival and well-being of the frogs and toads studied, apparently because a functioning pineal system presents a more rapid exhaustion of energy reserves. As a homeostatic mechanism, the pineal system of amphibians regulates metabolic activities within certain limits by influencing the animals’ basic behavioral patterns.

COMMENTARY
Experiments of the kind performed by Mr. Adkins hold a special fascination, for they cut across disciplinary boundaries and appeal to persons working in a variety of biological fields. Thus, the present study has implications for habitat selection that will gain the attention of the ecologist. The student of animal behavior will also find material of interest here, as will the physiologist and the physiological ecologist.

The Adkins experiments have the virtue of simplicity; another worker with relatively limited resources could easily repeat the work on the same or other species. But an uncomplicated approach does not necessarily go hand-in-hand with uncomplicated and easily interpreted results. Here we find data on behavioral and pigmented response to light, chiefly in conditions of thigmotactic responses, and reaction to outside disturbances, all as related to the intactness—or absence of shielding—of the pineal organ.

The pioneering aspects of this initial work on frogs and toads necessitates that comparisons be made with related forms, so the apparently parallel results found between such different animals as these frogs and the lizards studied by other workers are of particular interest. A lizard that basked in the sun and a frog that is largely nocturnal both respond to removal of the stigmorgan by increasing their exposure to light. Yet investigation of the lizard-like tuatara of New Zealand (a reptile only distantly related to lizards), studied after Mr. Adkins did his research, revealed that this animal made no behavioral response to interference with its parietal eye. Removal of the stigmorgan of tadpoles has likewise produced no positive results. Perhaps the only possible prediction is that the results of any new experiment on the pineal system are unpredictable. Indeed, the stigmorgan of frogs and the parietal eye of lizards may not even be homologous structures, and we may in effect be comparing apples and turnips.

The observations on reactions to outside disturbances again are parallel in lizards and frogs, the operated animals being less shy. But Adkins’ suggestion that the frogs are responding to sound should be documented carefully, for many observers have noted that frogs (with the exception of females seeking their courting mates) are notoriously unresponsive to sounds. The piercing “fright scream” of a leopard frog seized by a predator, a horrid sound to human ears, produces no grossly visible response in other frogs.

TADPOLES
The behavior of stigmorgan-less (or parietal shielded) frogs and tadpoles is altered rather subtly, if indeed it is altered at all. Hence, if normal variation
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in behavior is to be distinguished from true changes induced by the experimental conditions; it is important the experiments be performed on a large number of animals. In future experiments, Mr. Adkins and his successors should utilize larger numbers of animals and determine whether factors such as sex, breeding condition, and body size (or age) influence behavior patterns.

Other possible angles in future study suggest themselves. For example, the study of internal physiological rhythm in animals is currently attracting the attention of many workers. We may wonder, for example, if the toads would have been found behaving in the same fashion if observed at 10:30 p.m. and 2:30 a.m. instead of during daylight hours.

Whenever possible, different species undergoing test should be exposed to the same experimental conditions. Such comparisons between the species can safely be made. In the present study the toads were exposed to a combined light and heat gradient, but the frog was subjected to relatively little temperature variation throughout their experimental chamber. As a result, we cannot directly compare the results of the two experiments. The more simple experimental conditions may in part explain the positive results obtained in the frog experiment.

One might object that the toad, like a standing organ, would be unlikely to respond as does the frog, but Adkins reports that both toads and frogs respond to starvation (or shielding of the parietal region) by adopting paler pigmentation than do unmodified animal and he goes on to relate the state of pigmentation to illumination.

In demonstrating a definite relationship between the pinel system and light in the leopard frog and southern toad Mr. Adkins has made a unique and valuable contribution. Because the field research into which he has probed is most difficult, both his initiative and his energetic and thoughtful work are the more to be commended. We trust to experience in this initial study will encourage Mr. Adkins to further research.

Richard C. Zweifel

This list details the photographer, art, or other source of illustrations, by page:

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COVER: Seen here is a commonplace but remarkable animal—the starfish. The photograph shows part of the ventral surface of the creature's arms, from which the tube feet project in double rows. In his article, which begins on page 10, Dr. Allison Burnett, of Western Reserve University in Ohio, discusses the complex anatomy of the starfish. Dr. Charles Walcott, of Harvard University, made the photographs that illustrate the text in a salt-water aquarium at the Smith School, Lincoln, Mass. Drs. Burnett and Walcott have teamed up before on these pages, in an article on the hydra (NATURAL HISTORY, November, 1939).

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The American Indian in current books

By JOHN C. EWERS

The needs of the North American Indians, as outlined by their representatives during a conference last summer at the University of Chicago, have received much interest in the last year. Now, on the "Frontier of the 1960's," there are healthy signs that move and more Indians, disturbed by stereotyped and inane misrepresentations of their people, are appraising the current condition of their culture and Indian-white relations. Echoing the interest of the Indians themselves, books published in 1961 show a remarkable variety of attractive and informative works on Indian history, lore, art, and general culture. At the same time, many non-Indian Americans, stimulated by scouting and camping programs, by visits to museums, and by travels in our own country, are rediscovering the Indians. These initiatives are becoming more aware of the rich contributions Indians have made to our American heritage, and they are recognizing that Indians have been, are, and will remain a significant part of our national folk tradition. However, the very abundance of books on Indians is perplexing to anyone seeking a reliable picture of these people. A recent bibliography of writings on the North American Indians, of particular value to anthropologists and historians, lists more than 17,000 titles, and there must be thousands of other highly colored, romantic, or superficial books and articles that have been written for popular consumption. The interested layman sorely needs a guide to help him to select books that are both readable and worth reading.

Probably the greatest need is for a single volume providing a comprehensive, factual introduction to the historic Indian tribes and cultures of North America. As early as 1917, Clark Wissler, then Curator of Anthropology at the American Museum of Natural History, published The American Indian, a general introduction to the Indians of North and South America. Long regarded as a classic in its field, this volume was revised and reprinted in 1922 and again in 1938. But so rapidly have new technical studies in this field been published in recent years that Wissler's book is out of date. Harold E. Driver's Indians of North America is a worthy successor to Wissler's classic, insofar as the Indians of North America are concerned. It is a systematic, sound description of the ways in which the Indians lived before their traditional customs were altered greatly through contacts with European civilization. As did Wissler before him, Driver has grouped the hundreds of tribes by culture areas to facilitate description and to demonstrate clearly the ingenuity of the Indians in making use of the resources of different environments. Early chapters in this book tell of the origin of the Indians, comparing the ways in which the historic tribes of fourteen culture areas made their living. Descriptions of primitive Indian methods of raising crops and of Indian hunting techniques comprise some of the most fascinating sections of this very informative book. Later chapters deal with Indian housing, clothing, arts and crafts, music, trade and transportation, property, marriage and family life, government, warfare, education, and religion.

In virtually all of these aspects of life, incidentally, the achievements of the high cultures of Meso-America contrast sharply with the more modest ones of the Indians who lived north of Mexico. The concluding chapter impressively summarizes the Indians' contributions to world culture, emphasizing the fact that nearly half of the modern world's food supply is obtained from plants that were first domesticated by the American Indians. Carefully prepared maps graphically portray the locations of cultural areas, the natural vegetation areas of the continent, the relative density of Indian population, the distribution of Indian languages, the dominant types of subsistence, and the distribution of particular traits of material and social culture such as the cultivation of maize and cotton, the use of alcoholic beverages, horse types, clothing materials, use of weaving devices, pottery-making and method of tracing family descent. A larger end-pocket map names and locates all the historic North American tribes.

Taking up the Indians' story when Dr. Driver has left off, William T. Hagan's American Indians traces the history of Indian-white relations in the country from early colonial times to the present, particularly emphasizing the effects upon the Indians. His portrayal of the transformation of tribe after tribe of courageous, independent red men is depressingly effective; dependent reservation dwellers do not make a pretty story. Throughout the long period of the " Winning of the West," land-hungry frontier men justified their seizure of Indian lands with the pious declaration that God and nature did not intend that such fine land should be monopolized by savages who were incapable of developing it. In the bloody business of advancing the frontier, white men often failed to discriminate between friend and hostile Indians, while the retreating Indians were unable to forget their still older intertribal differences long enough to present a united front against the white intruders. In the Colonial War Indians fought the white man's battle on both sides, while in subsequent conflicts Indians aided the whites in fighting neighboring tribes who had long coveted them. Able chiefs led hostile tribes to dramatic victories over the white man, but they could only delay the inevitable conquest.

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in the white man’s image, prohibiting traditional religious ceremonies, urging the Indians to worship, dress, and work like white men, sending their children to school, and dividing their tribal owned lands into individually owned allotments. Paternalistic policy-makers thought they knew what was best for the Indians, who had no voice in Indian affairs. While the Indians’ numbers grew rapidly during the first three decades of this century, their lands continued to slip away into white ownership. The Indians remained apathetic, impoverished, and stubbornly resistant to the white man’s efforts to assimilate them into his culture.

By the late twenties it was becoming apparent to students of Indian affairs that doing the Indians’ thinking for them was not getting results. Then, in 1934, an Indian Reorganization Act initiated a new policy. The Indians’ right to retain their traditional customs was recognized. Indian tribes were encouraged to organize and to engage actively in the management of their own affairs. After generations of being told what to do, it required time for Indians to become accustomed to thinking for themselves, but the new policy stimulated Indian initiative. However, of recent years progress has not been rapid enough to please some non-Indians eager to push the Indians out into the main stream of American life. Other students of the Indian problem think the Indians are not yet ready for such a perilous adventure. Dr. Hagan clearly and calmly describes the issues without taking sides in this present controversy. His book provides a background that will help thinking Americans to form their own opinions of any solutions that are proposed for the complex Indian problem.

George Irving Quimby’s Indian Life in the Upper Great Lakes traces the Indian occupation, from about 11,000 B.C. to A.D. 1800, of the more than 200,000 square mile area that includes the drainage basins of Lake Superior, Lake Huron, and Lake Michigan. After the glaciers retreated, shaggy mammoths and mastodons moved in, and the Indians who followed them and killed them with stone-pointed spears were the first humans known to have lived in this region. They were succeeded by hunters who made woodworking tools of ground stone and by Indians who fashioned tools and weapons of copper and hunted elk and barren-ground caribou. These Old Copper Indians, who may have lived as early as six or seven thousand years ago, may have been the world’s first fabricators of metal tools and weapons. Indians of the Early Woodland Culture, during the period 500 to 100 B.C., were the first of the Upper Lakes people to build mounds of earth over their dead, and the first to make pottery. Then Indians of the Hopewell Culture moved in from the south. They introduced agriculture into this northern region, built more elaborate earthworks, excelled as artists and craftsmen, and traded widely with distant tribes. During the period A.D. 800 to 1600 a great differentiation of cultural groups took place in this region leading to the development of the Indian tribes met by the early European explorers of the western Great Lakes— the Miami, Sauk, Fox, Potawatomi, Ottowa, Huron, Chippewa, Menomini, and Winnebago. The last third of Quimby’s book describes the aboriginal customs of these historic tribes, the change wrought by the introduction of useful European-made objects in the early years of the fur trade, and the break down of traditional ways of life among these tribes under the impact of the advancing frontier of white settlement. This full account of more than 12,000 years of Indian life in the upper Middle West is told with that disarming simplicity found only in the writings of a scholar who has mastered his subject so thoroughly that he can tell it to the layman without complicating the narrative by technical jargon. Carefully drawn maps, sharp photographs, and drawing of the artifacts typical of each prehistoric culture, as well as reproduction of drawings of Indian life in the early historic period by contemporary artists, add greatly to the reader’s enjoyment.

A nother well-written regional account is W. W. Newcomb, Jr.’s The Indians of Texas. Although the prehistory of the vast state of Texas is less well known than that of the Upper Great Lakes, it is clear that Indians hunted the now extinct elephant on the Plains more than 12,000 years ago. Among other fascinating prehistoric finds in Texas are the remains of a woman, popularly referred to as “Midland Minnie,” whose true age is questionable but may be well into the thousands of years. Within the rambling boundaries of this huge state, Indians of four different cultural traditions reside in historic times. The warlike Comanche and neighboring, buffalo-hunting horsemen of the Plains, who moved southward into Texas in the eighteenth century need little introduction to most Texan and to many other Americans. But many other Texas tribes are little-known save to a few students. Among them were the Karankawas of the Gulf coast and the Coahuiltecan tribes of south Texas. The latter eked out an existence in an attorney by devours almost everything in their environment that the human organ
ion could digest—fish, cactus, fruits, mesquite beans, ant eggs, deer dung, and even human flesh. The Jumano and related tribes along the Rio Grande were little-known gardeners whose cultural affiliations were with the Pueblo Indians of the southwest; while in east Texas the Indians of the populous Caddo confederacies, the most advanced of the Texas tribes, were highly successful agriculturalists who also built temples as centers for complex religious ceremonies.

Newcomb’s well-organized book suggests the origins, describes the customs, and traces the history of each of these diverse cultural groups. Time has dealt harshly with the Texas Indians; many tribes have become extinct, while others found refuge outside this state. Not a single Indian tribe remains within the vast limits of our second largest state.

The Assiniboines, by James Larpenteur Long, is of particular interest because both author and illustrator were Assiniboine Indians. Mr. Long, a grandson of a fur trader, Charles Larpenteur, and an Assiniboine woman, gathered his information in the native tongue through extended conversations with aged Assiniboines who had vivid recollections of tribal life in buffalo days. In simple, straightforward language Long tells of the traditional customs of his people—how they hunted buffalo, moved camp, carried upon enemy tribes, made pipes, beadwork, and other artifacts, played games, treated the sick, and performed social dances and religious ceremonies.

Many interesting details of old-time Assiniboine life not reported elsewhere are given in this book, and some of the major points are illustrated by short, telling reminiscences of older Indians. The Assiniboines, one of the largest tribes of the northern plains, were a conservative people, the poor relations of the mighty Sioux. They owned few horses and continued to practice some of the customs of prehorse days long after their wealthier neighbors had abandoned them. Although the author does not emphasize his point directly, his information tends to support it. He shows the survival of heir custom of buffalo-hunting on foot, heir heavy reliance upon dogs for transporting camp equipment, and their public recognition of young men who were wise, long-winded runners.

This book should appeal to older children as well as to adults. It is cleverly illustrated by line drawings, executed with a touch of humor by William Standing, a young Assinibow artist, whose promising career was cut short when he died in an automobile accident.

One of the most important, if least known, tribes among the powerful western Sioux, the Brule, now has its dramatic history told in George E. Hyde’s Spotted Tail’s Folk, Hyde con-

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"Mountain Wolf Woman," one of the most unusual Indian books of the year—the autobiography of a charming, outgoing, 74-year-old Winnebago Indian woman, as it was tape-recorded at the request of her adopted niece, the anthropologist Nancy O. Lurie. Far too little attention has been given to the roles played by valiant Indian women during the long and difficult period of family readjustment to markedly changed conditions of life in a dominantly white man's world. Men, deprived of their traditional roles of hunters and warriors, were easily discouraged and frustrated. But Indian women, by carrying on their age-old routines as wives, mothers, and homemakers, provided that continuity needed to enable their families to survive. Mountain Wolf Woman was such a woman. With good humor and no bitterness she recalls her experiences in the changing culture of her tribe. Born in 1881, when the Winnebago could still make a living by hunting and gathering wild roots and berries, she early learned to help her mother with the household chores. Her education at a mission school was abruptly ended in the sixth grade when her older brother insisted that she marry a total stranger who had done him a very minor favor. Mountain Wolf Woman’s description of her Indian-style wedding to this unknown and unloved man is one of the highlights of her story. She goes on to relate her memories of a later and more successful marriage, her vivid religious experiences as a participant in the peyote cult, and her pride in her children and grandchildren.

Simple life-story of a Woodland Indian woman is a rich human document. Dr. Lurie’s introduction, describing how the story came to be told, and her explanatory notes on the old Winnebago lady’s reminiscences make this book doubly interesting to all those readers who are not familiar with the customs of the Winnebago Indians.

Surely the handsomest Indian book of this or any previous year is Frederick J. Dockstader’s Indian Art in America. It presents 250 technically superb photographs of carefully selected examples of the arts and crafts of the prehistoric and historic Indians of America north of Mexico. Seventy plates are in magnificent color. Each object is briefly identified by size, approximate date, and locality or tribe of origin; its function (if known) is also described. Most of these masterpieces of Indian workmanship are from the collections of the Museum of the American Indian, Heye...
Foundation in New York City, of which Dr. Dockstader is the Director. Together these specimens illustrate Indian achievement in such varied techniques as wood, stone, and ivory-carving; modeled and/or painted pottery; painting on wood, hide, and paper; basketry, textiles, silverwork; embroidery in porcupine quills, moose hair, and trade beads. The number and variety of works depicted—few has been pictured before—are sufficient to demonstrate the wide range of regional styles in Indian arts and crafts. Especially rich is the portrayal of carved and painted masks and other examples of the woodcarving skills of the Indians of the Northwest coast, who created one of the world's original art styles. One of the most striking color plates shows an exquisitely carved and painted wood mask from the Salish-Indian region at Key Marco, Florida. This and other prehistoric examples of southeastern Indian art reveal the high level of achievement attained in that region before the first white men landed on our shores. In other regions Indian art was greatly stimulated by the acquisition of metal tools, glass beads, and other materials of European manufacture. Some of the reproducing pictures in this book are the reproductions of meticulously drawn and brilliantly colored water colors created by modern Indian artists of the Great Plains and southwestern America.

In his concise introduction, Dr. Dockstader points out the considerable antiquity of Indian art in North America, describes the development of regional styles, traces the history of particular arts and crafts, and explains their functions in Indian society. Many examples of Indian art have an immediate appeal to non-Indian viewers, yet it warms again trying to judge Indian art by non-Indian standards. As a member of the Indian Arts and Crafts Board of the United States Department of the Interior, Dr. Dockstader has actively encouraged contemporary Indian artists and craftsman and aided them in finding markets for their creations. He makes a strong plea for wider understanding and appreciation of this only true native art of North America. This beautiful book is likely to remain for many years the outstanding volume on North American Indian arts and crafts.

Among the many implications to emerge from a consideration of these books, one point is clear: so great was the variety of Indian cultures on this continent that no single tribe can be considered typical of all the Indians in North America or even in the United States. Anyone asking questions about Indians must specify a tribe or area if he expects to receive specific answers.

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Enigma of an Echinoderm

Much of the starfish’s biology remains a scientific mystery

By Allison L. Burnett

To the untrained eye the starfish seems to “have little excuse for being alive.” The animal possesses no excretory system, no circulatory system, and only the most primitive respiratory system. This would not be too disturbing were it not that most biologists agree that the phylum Chordata, of which man is a member, arose in evolution directly from the phylum Echinodermata (spiny-skinned), which contains the starfish as one of its principal members. Anyone who has seen a starfish slowly gliding over the surface of the ocean floor would certainly be hesitant to claim this creature as a distant cousin.

Thus it is interesting to penetrate beneath the surface of the starfish’s piny exterior and examine the animal closely from the anatomical and physiological point of view in an attempt to determine why the starfish is placed in such a distinguished position next to the chordates on the phyletic, or evolutionary, tree. Externally the common starfish, Asterias rubi, consists of a central disk from which project five long-pointed arms. On the ventral, or oral, surface of the disk is a mouth-opening that leads almost directly to a large stomach consisting of two chambers. The stomach is practically all of the area occupied by the central disk. The intestine, which leads from the stomach to a small opening on the dorsal surface of the central disk, is only a few millimeters in length and is usually unnoticed during cursory dissection of the animal. The anatomy of the arms is identical. Two large paired digestive glands run the length of the arm and are connected by ducts to the stomach. Under the digestive glands are a pair of gonads, connected to the outside medium by pores located at the base of the angles formed where the arms are attached to the central disk. Externally, two rows of locomotory structures, the tube feet, are found along the entire length of the ventral surface of each of the animal’s arms.

From this simple anatomical discussion, the starfish appears to be on a relatively low level of organization. However, it possesses one of the most complex nervous systems to be found in the invertebrates; its feeding mechanism is unique in the animal kingdom; its method of locomotion is extremely complex, and is not duplicated outside of the phylum Echinodermata; and finally, the animal’s ability to drop an arm when it is disturbed and to regenerate into a complete animal from only a small portion of the central disk is not equaled by any of the higher invertebrates.

Because of the devastation starfish cause in clam and oyster beds, man has sought a long time for methods to control the starfish population. Therefore one would imagine that the starfish has been studied thoroughly by modern scientists from the physiological point of view. Yet less is known regarding the physiology of the starfish than of any other major invertebrate animal. The nature of its digestive enzymes, the mechanism employed by the animal to drop an arm, the physiology of its nervous system, the cellular changes that occur during the regeneration process, the regulation of its locomotory apparatus, and the transportation of food materials within its body are still matters of highest speculation. Furthermore, it is only within the last decade that the mechanisms involved in the animal’s feeding process have been elucidated to any considerable extent.

So let us begin by examining what is known concerning the biology of the animal, and end by considering the many interesting problems that are or will be foremost in the experimental program of the modern student of the echinoderms. We will start with a kind of scientific detective story that has been written by investigators during the past 100 years. The problem is: how does a starfish succeed in opening the valves of a clam for the purpose of devouring it? Although the starfish leaves few clues behind except an empty clam shell, it is possible to “catch the starfish in the act,” experimentally, so to speak, and here we have been able to find the answer to a most bewildering problem that, unfortunately, still does not solve the very important economic problem of how to prevent the crime.

Since the time of Aristotle naturalists have observed that starfish are capable of attacking, opening, and digesting oysters and clams successfully. Furthermore, one would strongly suspect that many primitive tribesmen who feasted on mussels and oysters long before the time of Aristotle must surely have witnessed the dazed starfish gliding over the valves of the help-
less shellfish and feeding on the soft parts of the trapped animal for, under natural conditions, starfish always abound wherever shellfish beds are found in abundance.

The decimation of shellfish beds was probably no problem for primitive man or even for the early settlers in this country, since enough clams always escaped the ravages of the starfish attack to provide food for local populations. However, as the population of this country grew, the raising and harvesting of clams became an enterprise rather than a means of survival. As early as 1891 it was estimated that the damage done by starfish to oyster beds in Connecticut alone was approximately $163,000, $613,500, and $412,250 for the years 1887, 1888, and 1889, respectively. In fact, in 1901 the state of Connecticut passed a law stating, “Every person who shall willfully deposit or assist in depositing starfish...in any of the navigable waters of this state...shall be fined not more than fifty dollars or imprisoned not more than six months.”

In spite of the notoriety given the starfish by state judiciary committees, Little was known until the last decade regarding the mechanisms controlling the feeding habits of the animal.

First let us observe the basic movements employed by the hungry animal in search of its prey. By means of its dozens of tube feet (to be discussed later), the starfish moves smoothly over the ocean floor. If a clam is in the immediate vicinity with its valves slightly open, the starfish will suddenly veer off in the direction of the clam. When the first arm of the starfish makes contact, the clam immediately closes. The starfish glides over the surface of the clam and assumes a humped position, which it may maintain for several hours. Then it moves away. An examination of the clam reveals that all its soft parts have been devoured, and that nothing remains except the two calcareous valves.

For one hundred years investigators have sought the mechanism by which the starfish gains access to the interior of the valves. The hosts of investigators who have examined this process may be placed in two major schools. The first group hypothesized that the starfish secretes a poison between the valves, killing the clam and causing its muscles to relax and the valves to open. The second group maintained
that the starfish opens the clam by sheer force. More support was given to the “poison” school than to the “force” school until fairly recently.

Experiments were undertaken in our laboratory to ascertain which of the foregoing theories could be supported by experimental evidence. First, it was desirable to determine whether the surrounding sea water could penetrate into a clam after it closed its valves. If the starfish did indeed secrete a poison, then the poison would be useless unless it was capable of passing between the clam’s valves to the soft parts of the animal. The common Venus, or cherrystone, clam was employed in this experiment. Several clams, whose valves were closed, were tied with cord so that it was impossible for the valves to open. These were then placed in a solution in which were suspended microscopic carmine particles. It was assumed that if there were even the smallest opening between the valves, the carmine particles would enter and be found inside the animal after it had been removed from the solution. Upon examination, the clams that had been left in a carmine solution for three days showed no particles in their valves.

This observation implies that poison secreted by a starfish would have no way of entering between the valves of the clam. To further test this hypothesis, another simple experiment was conducted. Eight clams were bound with heavy cord so that their valves could not be opened, and were placed in an aquarium containing a dozen hungry starfish. If a starfish, in attempting to open such a bound clam, injected a toxic substance between the valves, the clam would show some noticeable effect after the starfish had given up in its feeding attempt. All of the clams were attacked by the starfish in the next few days. Some of the starfish were frustrated early by the bound clams and gave up their feeding attempts after eight hours. Others, however, remained humped on the clams for forty-eight hours before crawling away. In all cases, careful examination revealed that none of the bound clams was harmed by the starfish. The clams’ hearts were perfectly intact and beating regularly. These experiments further suggested that either no poison was being produced by the starfish, or that if a poison was produced it could not enter the clam’s tissues because of
the protection afforded by the clam’s “hermetically sealed” valves.

It was decided to attack this problem from another point of view. It appeared possible that the starfish might open the valves slightly through force and then inject a poison between them. In order to test this hypothesis, a small V-shaped notch with an area of approximately 1 to 2 mm.² was filed at the edges of the valves of three clams. The valves were tied shut as before, and the clams were offered to hungry starfish. Upon removal of the clams from the predator, it was noticed that practically the entire stomach of the starfish had passed out of its mouth-opening into the tiny hole in the clam valves. It had been known for a long time that the starfish was capable of evertting its stomach during feeding, but the present observation revealed that this large stomach could work its way through an extremely small opening (4/100 of an inch). The clams, furthermore, were almost completely digested.

Bits of the feeding picture now began to fall into place, but a few additional experiments were necessary before anything definite could be said. Small pieces were broken from the valves of several clams, but on this occasion the opening in the valves was covered with a very fine bolting cloth. The clams were then bound in heavy cord, similarly to those in the preceding experiment. However, the intervening bolting cloth prevented the starfish from passing its stomach between the valves. The clams were placed in the water with several starfish. “Clam juice” diffused into the water, and within minutes starfish, hanging on the sides of the glass aquarium began to glide down to the bottom and, without hesitation, make their way to the clams.

When the starfish had given up in their feeding attempts and had moved away, the clams were examined. Astonishingly enough, although the soft parts of the clam had never been in contact with the starfish, the clams had been digested! This experiment clearly demonstrated that the starfish possesses an extremely powerful enzyme within its tissues. This enzyme is capable of digesting a clam even after being diluted in sea water and clam juice. Since, however, it was well known that enzymes usually do not digest living tissue, it was still possible that the starfish secreted a combination of a poison and an enzyme simultaneously. Thus, the poison would kill the clam, after which enzymatic digestive action would begin.

In order to test this hypothesis, the foregoing experiment was repeated, but on this occasion, clams were removed from the starfish at different intervals during the feeding process. It was found that after two to five hours several clams had had parts of their external tissues digested, but their hearts were still beating. Thus, it was shown concretely that the enzyme produced by the starfish is literally capable of digesting a clam alive! It was not necessary to postulate that the starfish possesses a poison specifically designed to kill clams.

ONLY one major problem remained to be answered at this time. Even if the starfish is capable of secreting an enzyme that will digest a living clam, how does the enzyme reach tissues that are hermetically sealed? Since it had been shown that the starfish could pass its stomach through an incredibly small opening, it appeared possible that if the starfish were capable of pulling open valves of a clam a mere 4/100 of an inch, then it would be able to evert its stomach, pass its stomach between the
valves, and begin enzyme secretion. Anyone who has ever attempted to open a good-sized *L. variegatus* clam by simply pulling the valves apart realizes that it takes a tremendous force to accomplish this feat. Earlier investigators had argued that the starfish need not apply such a force to the clam at all. They claimed that if the starfish applied a steady small force, the clam's muscles would eventually tire and the valves would open.

An experiment was undertaken to determine, first, if the starfish could open the valves through sheer force, and second, if this was accomplished through a small force acting for a long period of time. A small notch was filed in the middle of the edge of the clam's valves. The hook of a spring balance (the type used by fishermen) was then inserted into the notch, and the force required to open the valves 1 or 2 mm. was recorded. After testing several clams it was learned that a force of 7 to 10 pounds was necessary in order to produce even this minute opening between the valves.

These clams were then forced open, and the muscle that normally holds the valves together was severed. The clams were then wrapped up with strong rubber bands until a force of 12 pounds was required to pull them open with a spring balance. It was reasoned that if a starfish could open a clam with a resistance of 12 pounds, it could also open normal clams whose average resistance to opening is only 7 to 10 pounds. Furthermore, the rubber bands, unlike normal muscle, would not be subject to fatigue.

Several clams whose adductor muscles had been severed were then wrapped in rubber bands and dropped into a tank containing several starfish, which invariably attacked them. Often a portion of the valves protruded between the arms of the starfish, making it possible for an investigator to determine whether or not the valves were being forced apart. After the starfish had assumed their humped feeding position, it was noticed that a definite gap of about 2 mm. appeared in the valves of the bound clams. After a few minutes the valves snapped shut again, presumably upon the everted stomach of the starfish. This alternate opening and closing of the valves often continued for approximately a half hour. By that time the starfish had oriented itself perfectly and was able to hold the valves open for as long as 10 minutes at a time with ease.

By inserting hook of spring balance into notch filed at valve edges, it was found a force of 7 to 10 pounds was needed to pry clam shell open.

Twelve pounds of force was required to pry open shells bound with rubber bands. Starfish ate clam, proving it could easily exert this much force.

Thus, the starfish-clam mystery is largely solved, but many questions still remain to be answered. First, if the starfish everts its stomach, how is it able to ingest food materials from the digested clam, and second, how is it able to evert and withdraw its stomach? Anderson (1934) has studied this problem in some detail. He has shown that the stomach of the starfish is lined with cells that bear a tiny whiplike thread or flagellum on their surfaces. These flagella, by whipping strongly back and forth, produce a current of water that passes back into the part of the stomach that has not been everted on feeding. This water current carries with it many digested food particles from the clam's tissues. The particles either are absorbed by the cells in the stomach or pass into tubes that lead to the large digestive glands lying in each arm. Here the food materials are absorbed by special digestive glands. There is also good evidence that cells in the digestive glands secrete the powerful enzymes that digest clam tissues.

The eversion process itself is more of a mystery. Anderson believes that during the eversion process the longitudinal musculature around the mouth-opening contracts, forcing the
The fact that increased pressure inside the body cavity of the starfish causes the stomach to evert through the mouth can easily be demonstrated. If 5 cc. of sea water are injected into each of the starfish's arms to increase the internal pressure in the animal's body cavity, the stomach will evert through the mouth-opening. Connected with the stomach are small paired muscles that run from the stomach into each arm, where they are anchored. It is supposed that upon retraction of the stomach the muscles in the arm relax, releasing the pressure of the body fluids upon the everted stomach. At the same time both the small retractor muscles attached to the stomach and the muscles in the wall of the stomach contract. This serves to pull the stomach back through the mouth-opening. Such a feeding method has no counterparts in the animal kingdom.

Earlier it was said that very little is known concerning the physiology of the starfish. The reason is that until a few years ago, no one had been able to operate on the animal with any success. If one is interested in knowing the function of the digestive glands in each arm, for instance, the natural experimental approach would be to extirpate or to ligature the ducts leading to this gland and to see how the biology of the animal is affected. However, if a cut is made in the starfish's arm to reveal the digestive gland, the investigator finds that while he is working on the arm, the rest of the starfish, consisting of the central disk and four arms, has moved away. This process of dropping off a part that has received a noxious stimulus is called autotomy. In other groups of animals, such as the arthropods, many species have a weakened area in each limb. This breaks when the animal tries to escape from an attacker who has seized a limb. No such weakened area appears in the starfish in spite of the fact that the arm breaks at the same point whenever the animal is disturbed. If one forcibly tears off a starfish's arm it will not break at the point where it does when an incision is made in the arm during an operation. The starfish itself is the sole determiner of when and where the arm will be broken. The author has found that if a strong electric current is applied to the central disk of the animal, all five arms will walk away from the body, leaving the central disk alone under the electrodes. Examination of this process reveals that during autotomy the tissues at the base of the arm become soft and partially liquified. All the muscles' connective tissues in this area are involved in this "softening" process. The mechanism of the autotomy process, the changes that occur in the degenerating connective tissue and muscle, and the exact nature of the stimulus required to cause autotomy are questions that are still unanswered. Preliminary evidence suggests that the nervous system is involved in the process. Anderson found that if the starfish is immersed in an anesthetic (such as magnesium chloride in sea water) it will not autotomize its arm during an operation. This was a very important step in the scientific history of the starfish, as it is now possible to operate on the animal. After the operation, the starfish may be placed in normal sea water. It recovers admirably from the anesthetic, and does not appear disturbed.

One might wonder what happens to the starfish that drops its arm in the autotomy process. The answer to this question was learned by fishermen who removed starfish from clam beds, hacked them to pieces, and threw them back into the water. Each of the excised pieces promptly started to regenerate, and the hapless fishermen finally realized that by chopping up the starfish they were only increasing their numbers. It has been shown that an arm plus only a very tiny portion of

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Dr. Burnett, whose study of hydrias appeared in this magazine in 1959, is Associate Professor of Biology at Western Reserve University in Ohio.
the central disk will completely regenerate into a normal animal. The processes occurring in the tissues during regeneration are only now being studied in any great detail.

Another major system, which has not been discussed, is that controlling locomotion. The starfish possesses one of the most remarkable systems of locomotion in the entire animal kingdom. On the dorsal surface of the central disk is a small, porous, calcified plate called the "madreporite plate." Currents in a canal leading from the madreporite into the interior of the animal cause a flow of water to enter from the outside. These currents, like those in the stomach, are produced by hairlike structures lining the inner canal. The water is ferried through a series of canals until it reaches the arm. Here small off-shoots from the main canal system lead into each of the many tube feet that can be seen lying in two rows along the animal's ventral surface. The tube feet have a unique structure: inside the animal the tube foot is represented by a sac filled with water; outside is a stalk connected directly to the sac. At the end of each stalk is a suction cup. When the starfish moves, each of the sacs contracts, forcing water into the stalk portion of the foot. This causes the stalk to lengthen greatly. When the suction cup comes into contact with a surface, the tube foot becomes attached. After attachment, the longitudinal muscles of the stalk contract. This contraction serves to force the water back into the sac and to draw the starfish forward. The process can easily be visualized if one imagines throwing an anchor line from a boat to the shore. If the anchor line contracts, the boat moves shoreward. The starfish moves by constantly throwing out hundreds of these anchors. It will be recalled that during feeding the starfish glides over the clam and pulls it open. The attachment of the starfish to the clam is accomplished by the dozens of suction cups that the starfish has applied to the clam valves. Their combined force must restrain a force of at least twelve pounds, as was shown in the earlier experiments.

When one considers that the starfish has five arms, all radiating away from the central disk, it is apparent that when the starfish moves forward only one arm is in the lead. The two arms that are behind the lead arm are pointed to the sides of the animal, and those in the rear are also, in a sense, pointing to the side. Therefore, when the starfish moves, the tube feet in the front arm must be extended directly forward, while those in the remaining arms must be projected to the side. If the starfish changes its direction another arm takes the lead and all the hundreds of tube feet must switch their direction in a perfectly harmonious manner. Obviously, the nervous system of the starfish must be exceedingly complex in order to regulate the walking movements of this multiplicity of feet. Smith (1947) has stated that the nervous system of a single starfish, with all its various nerve ganglia and fibers, is more complex than London's telephone exchange.

It was stated at the beginning of this paper that biologists are in general agreement that the chordates arose in evolution from the echinoderms. Evidence is based on the facts that early chordate larval forms are similar to those of echinoderms; echinoderms and chordates form their body cavities in approximately the same manner; both groups have an internal skeleton; and an energy storage compound found in vertebrates is also found in the echinoderms and nowhere else in the invertebrates.

We have found preliminary evidence indicating that still another major similarity may exist between echinoderms and chordates—the nervous systems of the two groups. It is a well-known fact that in the vertebrates two major types of nervous stimulation of muscles can be demonstrated. One group of nerves liberates adrenalin at the nerve ending and the other group liberates a substance called acetylcholine. These two systems are said to be reciprocal to one another, that is, if the liberation of adrenalin causes one type of muscle to contract, then the liberation of acetylcholine on the same muscle will cause it to relax, and vice versa. Through this reciprocal action our voluntary and involuntary movements are maintained. If our heartbeat is very slow, the addition of adrenalin will cause it to speed up. Further addition of acetylcholine will cause the heart to slow down.

Although some invertebrates have been shown to possess sensitivity to adrenalin, there appears to be no clear-cut example of an invertebrate that has adrenergic and cholinergic systems that can function reciprocally.
We have conducted several experiments to elucidate the mechanism of nerve action in the starfish. First, it was found that adrenalin itself is not effective. The closely related substance nor-adrenalin, which is found in the lower vertebrates, does have an effect when applied to the tissues of the starfish. In our studies we have tested the effects of nor-adrenalin and acetylcholine on muscles in the tube feet, mouth, stomach, body wall, spine musculature, and several other body structures. In every instance it was found that if acetylcholine caused contraction of a muscle, adrenalin brought about its relaxation faster than normal sea water. Furthermore, it was found that when nor-adrenalin is added to the apical muscles, which run the length of the arm, the muscles contract and the arm is lifted. Also, if adrenalin is added to the digestive glands, they lengthen. Such a lengthening could be caused by small contractile fibers that connect the glands to the body wall. When acetylcholine is added to these structures, the lifted arm relaxes and the digestive glands are shortened. Thus, there seems to be evidence that the starfish possesses a nervous system containing basic elements found in the nervous system of the vertebrates. If it is indeed true that no other invertebrate animal possesses such a reciprocal system, it is additional evidence for the evolution of chordates from echinoderms.

It should be realized by this time that the starfish, which occurs by the thousands along our Atlantic and Pacific coasts, is still largely a scientific enigma. Any of its systems that the modern investigator chooses to examine is open for study and will offer years of research material. It seems only proper to close with a quotation from Dr. Libbie Hyman’s great treatise on the echinoderms, which was published in 1955: “I also here salute the echinoderms as a noble group especially designed to puzzle the zoologist.”
A PAPIER MACHE BOWL — Kashmir, expertly hand colored in black and gold, with brass liner, useful as well as decorative. 6" long, $12.50 ppd.

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F ENAMELED BRASS PITCHER — India, hand engraved and colored predominantly in black with white and red accents. 11" high, $8.25 ppd.

G EBONY PRAYING MAN — Tanganyika, hand carved from a solid block of ebony. Approx. 8" high, $4.75 ppd.

H OWL CIGARETTE BOX — Burma, attractively hand lacquered bamboo, black with gold markings. 4" high, $5.35 ppd.

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THE AMERICAN MUSEUM OF NATURAL HISTORY, N.Y. 24, N.Y.
Expressive Art of Old Peru

Metal, stone, and pottery speak silently today of pre-Incaic Peru, whose peoples left no written records. But in their material possessions, such as utensils, ornaments, and textiles, the inhabitants of ancient Peru created durable messengers to bring their story to future scholars and art lovers. The perceptive photographs of Peruvian artifacts on these pages were made by Lee Boltin. These objects and other examples of art forms from the prehistory of Peru figure in the exhibition of “Art and Life in Old Peru” that opened this past September at The American Museum.
Cast silver figure, just over three inches tall, may be dancer dressed for harvest festival. Man holds cluster of five ears of corn.

Hammered copper plaque, more than a foot square, is from Chimú period. It represents a chief, a ruler, or perhaps a deity.

Six birds of sheet gold stand on a base made from a silver bar nearly nine inches long. Base served as mounting for this ornament.
Chimu period blackware water jar, almost nine inches tall, dates from century before conquest. The artist has copied a much older jar showing a Mochica warrior.

Water jar perhaps from eighth or ninth century B.C., nearly ten inches high, illustrates the skill of Cupisnique potters in creating areas of contrasting texture.

Water jar of early Nazca culture shows a swimming fisherman. Over eight inches tall, the jar shows traditional incised outlines plus newer, fired ceramic pigments.
Bird-shaped finial of cast copper, about four and a half inches tall, may have been for head of staff. Wings, eyes, are shell inlays.

Jar in form of duck, ca. A.D. 500 to 700, is four and a half inches high. Incised design is unusual in pottery of this period.
Water jar, nearly a foot high, resembles squash with a hawk's head in place of stem. It may have been made between A.D. 600 and 800.
A Continental Water Bird

The American white pelican nests inland

By ROBERT CUSHMAN MURPHY

That the pelicans are basically inland birds may come as something of a surprise, especially to Americans familiar with the southerly coasts of the United States, where pelicans are likely to be regarded as "sea fowl." That would be true, in a sense, of the brown pelican, which breeds along tropical and warm-temperate seashores of the New World; it has even crossed 600 miles of open ocean to establish itself at the Galápagos Archipelago. This leap, however, represents a unique maritime adventure in the history of the pelican family. All the eight species are strongly land-bound birds and most inhabit continental interiors during the nesting season.

The white pelican is a member of the inland group, even though much of its population reaches southern seacoasts in the non-breeding period. The species nests in western North America from Texas and the Great Salt Lake to British Columbia, Saskatchewan, and Manitoba, and eastward as far as the Dakotas. A few wander as far north as Great Slave Lake in Canada's Northwest Territories and there are scattering records from nearly all the eastern states. The winter range extends southward through Mexico to Guatemala.

John James Audubon, who wrote a delightful and scientifically sound biography of the brown pelican, became casually acquainted with the much larger white species when he moved from eastern Pennsylvania to Kentucky, on the banks of the Ohio River. He rightly regarded the huge bird as a visitor from the "Fur Countries," and added that he could give no account of its nest, egg, or young because he had never visited the territory in which it breeds. Nevertheless, in 1833 he christened it Pelecanus americanus with a characteristic Audubonian flourish: "I feel great pleasure, good Reader, in assuring you, that our White Pelican, which has hitherto been considered the same as that found in Europe, is quite different. In consequence of this discovery, I have honoured it with the name of my beloved country, over the mighty streams of which, may this splendid bird wander free and unmolested to the most distant times, as it has already done from...unknown antiquity."

Audubon, despite his peerless gifts, was ignorant of the fact that J. F. Gmelin, a follower of Linnaeus, had 49 years earlier bestowed upon the American white pelican the name Pelecanus erythrorhynchos, by which it is still known to ornithologists. The long specific name means "red-billed." Actually, the color of the beak and the naked skin around the eye is orange rather than red. Neither Audubon nor Gmelin had an inkling of the hypothesis that the American and Mediterranean white pelicans represent two branches of the same original, more widely distributed, preglacial stock. Divided and restricted by the Ice Age, each of these birds has since followed its own evolutionary course.

At the beginning of the breeding season the American white pelican grows a curious keel-shaped, horny ornament on the top of its beak. To be safe from predators the birds nest mostly on islands within lakes. The large colony here depicted is at such a site—the Anaho Island Wildlife Refuge, on Pyramid Lake, in northern Nevada. This is the largest nesting ground of the white pelicans in North America; it is estimated that 11,000 birds raise their young here. Sometimes the birds nest in a lake instead of on shore, as was true in Oregon before beautiful Klamath Lake was drained, quite unsuccessfully, for agricultural ends. In the Klamath water large floating mats of dead cattails and
rushed formed islets, through which
green shoots grew up each spring. On
such unstable platforms white pelicans
laid their eggs and reared their fam-
ilies among cormorants, ducks, gulls,
terns, and yelping avocets, the custom-
ary pelican neighbors.

The white pelican is one of our larg-
est birds, weighing up to 20 pounds
and having a maximum wingspread of
close to ten feet. Its nesting habits are
generally similar to those of the brown
pelican except that it never builds in
trees or swamp shrubs as does the lat-
ter. Two or three eggs are laid a year;
they are covered with a thick, chalky
deposit. The eggs are incubated for
about 29 days, and then hatch as
featherless, black, rubbery, and help-
less chicks. They grow rapidly, though,
and acquire a white down. By the time
they are half-grown, they begin to tod-
dle from the nest, and even to swim.

It is the feeding habits of the peli-
cans, of course, that gave rise to their
reputation for remarkable voracity.
Young pelicans are fed by regurgita-
tion; that is, they push their bills down
into their parents' pouches for pre-
digested food. A popular fallacy is
that the pelican stores food in its
pouch; actually it swallows the fish
soon after catching it. A less known
fact about the behavior of pelicans is
that the young, abandoned by their
parents before they have learned to fly

Flock of Pelicans, above, is a part of
the colony that nests at Anaho Island,
Pyramid Lake, Nevada—largest North
American breeding ground for species.
White pelican chick, with its black, rubbery skin, above, is newly hatched from one of the two eggs laid in this nest. Helpless now, bird will soon be able to toddle and swim, but mortality rate among pelican young is very high.

and forage for themselves, must live for a while on their own fat.

The white pelican's technique of fishing departs widely from that of the brown pelican. White pelicans never dive from the air; they wade or swim, usually in company, and scoop up prey by thrusting the head and beak beneath the surface. An adult can consume one-third of its own weight in the course of a single foray. Captive white pelicans quickly learn to catch fish tossed toward them, showing as much agility as toucans in a zoo snapping cherries out of the air.

White pelicans are scarcely graceful on the ground, but in flight neither swallow nor falcon can outdo them. The following description is from the pen of the Oregon naturalist, William L. Finley: "After returning from the fishing grounds and lounging about the nests for a while the pelicans began to circle over the colony in a large company, rising higher and higher till they were almost lost... flashes of white as the snowy breasts reflected a gleam of the sun. For hours the sky would glitter with these great birds as they soared about. Then it was thrilling to see some of them descend with... half-closed wings. They used the sky as a... toboggan slide and dropped like meteors, leaving a trail of thunder."
Adul pelican, above, could be approached only because it was too old to fly. Note characteristic webbed feet and the stretchable, almost translucent membrane that forms pouch.

Nervous and easily upset, a pod of immature pelicans will nestle together, left, when disturbed. They leave nests and waddle about, aiding weak legs by using wings as crutches.
This is the 113th of Nature Magazine's special educational inserts.
ONE OF THE MOST familiar words in public print these days is “coexistence,” a term used to describe that rather vague state of human relationships in which neither of two factions makes a hostile move for fear the other might prove stronger. The term, however, is not exclusively applicable to the social life of Homo sapiens; in quite another sense, there are also many coexistsers in the lesser ranks of the natural world. Among such are the lichens, which may possibly have been among the first forms of life to appear on earth. The lichens represent a successful plant interrelationship that might well be called a coexistence; and while, for the most part, they do not compete with other plants in their usefulness to mankind, they nevertheless deserve a better understanding on our part.

A lichen is never a single plant. It is invariably a close association of two widely differing and primitive plants, the algae and the fungi. Authorities disagree as to the nature of this relationship; but, whatever its true nature, it is at least workable within certain limitations. It is recognized that the algae concerned are green or blue-green, and are capable of manufacturing carbohydrates in the presence of sunlight, air, and water. It is also recognized that these algae can, and do, exist independent of the fungi, with few, if any, modifications. However, while the algae can exist alone, they are not so prosperous as when combined in a lichen, where they are held in place and anchored against removal by wind, water, or other disturbances. The algae function most effectively under optimum conditions of light, water, air, and temperature, where suitable minerals are available; but they can suspend operations without serious loss.

Some of the algae involved in the lichens were discussed in the sixty-ninth unit of this educational series, others are dealt with in textbooks on botany. No one family or genus of algae is involved in the lives of the lichens, and different species of lichens of one genus may entertain different species or different genera of algae as partners. The genera of algae most commonly involved are probably Protococcus, Pleurococcus, Nostoc, Gloeccapsa, Scytomena, Calothrix, Chroococcus, Xanthcapsa, and Trentepohlia. Interestingly enough, when these algae become involved in the lichen complex, they lose some of the characteristics exhibited when they are independent. They regain these if they are later freed.

There is at least one exception to the general rule that the fungi involved in the lichen complex are sac fungi, or Ascomycetes (a group that includes the yeasts, milwews, and the fungi that produce the antibiotic penicillin). Since the fungal part of a lichen association is more obvious to the human eye than the algal, the lichens are named after the fungus rather than the alga. In G.G. Nearing's *The Lichen Book*, published in 1947, more than a thousand species of lichens are recognized, and most of them are figured and described; yet, even then, Nearing's book does not attempt to describe all the known kinds of lichens.

The role of the algae in the lichen partnership is that of producing food for themselves and their partners, the fungi. If the algae have access to the necessary light and water, and the temperature is suitable, they produce food in any case; so, as we have said, they are relatively independent. But this is not the case with the fungus associate. The fungus in a lichen partnership cannot live independent of the algae for long; and although they may be the more conspicuous both in appearance and volume, the fungi are probably the more dependent upon the association type of existence.

The fungus partner is able to obtain and hold water—and water is a part of the lifeblood of every living thing. The fungus can also hold an established position; it is not easily washed away by water or blown by wind. This means that, once established, the fungus is not likely to be buried where sunlight and fresh air cannot
each it—a factor of great importance to the growing
society of alga and fungus that constitutes a lichen.
 fungi commonly are destructive agents, but in the li-
 chens they do not destroy the algal part of the “corpor-
 a tion.” Instead, they obtain their nourishment from
the algae without destroying them.
 Observers differ on the nature of the lichen associa-
tion. Some feel that it is purely incidental. Others
think that the partnership is of mutual importance, with each
partner contributing to the community and each taking
what it needs. Yet others claim that lichens are examples
of mutual parasitism. It would seem reasonable to as-
sume, from the success of the combination, that there
is a balanced relationship—in other words, a state of
peaceful coexistence.” There are advantages to this
sort of existence; but it is not necessarily the most suc-
 cessful kind of society, as we shall discover.

While the fungus-alga relationship has probably
been established since the emergence of living
things from the sea, it has been recognized by man for
less than a hundred years. In 1868, Schwendener an-
nounced that lichens were really a society of living
things, but his revolutionary idea was not immediately
accepted. In 1889, Bonnier—who had faith in Schwen-
ener’s idea—succeeded in bringing together “wild”
algae and lichen fungi to produce artificial or synthetic
lichens. It was early noted that, while the algae and fungi
were in close proximity to each other, the fungi did not
permeate, harm, or destroy the algae on which they were
dependent. The reason, or reasons, underlying this re-
markable aspect of plant association have never been
exactly determined. One of the most interesting features
of the association, though, is the obvious preference of
 certain species of fungi for certain species of algae (if
we may be here permitted to use the word “preference”).

The body of a lichen is basically that of the fungus
involved in the association. Generally, there are two
layers to the body tissue—the outer and inner—and the
algae may either be confined to one or the other of these
layers, or scattered through them. Three general body
types are recognized. These are the crustose, in which
the general form is ill-defined, except that a portion may
enter the support on which it rests; the foliose, which
possesses definitely recognizable holdfasts, and is a plant
body in many respects like that of a liverwort; and the
picose, which is erect, branching, or hanging.

There are four different basic processes that lichens
may go through to reproduce themselves. One is indi-
cated in the accompanying chart section, where we use
the term “sod flakes.” Sod flakes are merely small units
that may or may not be united, and which either grow
independently or associated with other units in the soil.
Each of these flakes may be considered an independent
plant, and bits of this basic tissue may become sepa-
rated to establish other independent plants merely by di-
vision. This, of course, represents the simplest kind of
production. Each segment of the original tissue has its
necessary complement of algae and fungi.

Another and probably unique sort of reproduction,

Dr. E. Laurence, Palmer, for many years director of
Nature Magazine's educational program, continues his
special inserts in the pages of the combined magazines.
Long Beard Lichen

Gold Eye Lichen

common among the lichens, is accomplished by structures that free little tangled masses of algae and fungi, which are ready to start new lichens when they reach a suitable location. The structures that free the little bundles of these two kinds of plants are known as soredia. Reproduction by soredia is only a short step from reproduction by fragmentation, since this latter process is merely the separation of small units of the algae and fungi essential to a particular lichen.

In both vegetative reproduction and reproduction by soredia, the close association of the algae and fungi is never interrupted. Many lichens also display structures that give the impression that they should be reproductive—as they are. These may be discs, cups, knobs, or other forms, which may either be hidden or held erect by branched or unbranched, colored or uncolored structures. Botanists call these apothecia. Although technically they are not true "fruits," these parts are commonly referred to as fruits, and we will do so here.

In this type of reproduction, the fruits are primarily structures that produce fungus spores. They do not necessarily produce the algae. Fungus spores may be freed independently of the algae, and success in producing a new lichen is dependent on contact of the fungus spores with the proper algae. It might appear that this sort of reproduction leaves much to chance, but it is successful. Once a new lichen or colony of lichens is established, it may exist for many years.

There is also a fourth kind of reproduction among the lichens—one that is seldom observed by any but the professional botanist. This is a true sexual reproduction, and concerns only the fungus part of the lichen. It is not common to all kinds of lichens, and is probably absent in most. In this case, procreation involves structures capable of producing real sperms and eggs. (Incidentally, the sperm cases are cast off and act as sperms, as in some
of the red algae that were discussed in the 38th and 110th numbers of this educational series.) The female structure in this type of reproduction also has some characteristics in common with the female reproductive scheme in some of the red algae. Here, however, we have only the space to indicate that sexual reproduction does exist in the lichens; we must leave the exact details to a good botany text.

In certain respects, the life-history of a lichen may be difficult to decipher. A lichen may lie dormant for a few days, for weeks, months, years, or possibly decades, and then resume its normal life activities when the conditions of its environment again become suitable. Parts of the lichen may die, leaving other parts to grow and develop perhaps as separate plants. Who can say where a lichen's life-history begins or ends in such a cycle?

**Whatever the locality, there is a definite seasonal growth activity in the lichens.** This activity may be outwardly indicated by a change in color of the plant, easily observed at a glance. The presence or absence of water may in some cases be of greater influence than temperature in promoting growth but, generally speaking, lichens in temperate regions exhibit more growth activity during late fall and spring than during the summer. Physical changes are so small in a single season that, unless some kind of a marker is employed, dimension changes may not be immediately apparent.

There is little doubt that the life span of a lichen is largely influenced by its immediate environment. When conditions change to allow rival plants to thrive, the life span of a lichen may be relatively short, since it cannot survive severe competition. Where competition is slight or non-existent, there is little to prevent a lichen from living for hundreds of years. For example, the life span of a lichen growing on a tree trunk would obviously be shorter than that of one growing on the surface of a...
of glacial boulder, where only minor changes take place over long periods. Biologically speaking, lichens in general may be considered as successful pioneer and frontier plants. They are not particularly “aggressive,” but they readily move into areas where their kind has not existed before. There are few places in the world where lichens are not found. They exist on the highest mountains, and at the edges of the seas. They are found at the tops of the highest tropical trees, where the blazing sun is too strong for competitors; or they may be found at the bottom of the same trees, where other plants are ruled out by excessive shade or moisture.

Certain chemicals are produced by the lichens that can dissolve the constituent minerals of solid rock. The plants are thus enabled to occupy territory forbidden to other plants. The rootlike holdfasts of lichens are not true roots, but they can penetrate solid rock to a depth of a few millimeters, and if there is a crack or crevice in the surface of a rock, lichen “roots” are able to move in to even greater depths, and take hold firmly.

As soil-makers, lichens perform a most important function. Water, penetrating the tiny crevices produced by lichen roots, freezes and wedges out rock particles, contributing to the manufacture of new soil and the renewal of old. When a lichen dies, its decayed body helps enrich the soil, perhaps to the point where the soil may sustain other plant life. Lichens may sometimes serve as indicators of the nature of soils. Many mountain rodents and many Arctic birds of prey select elevated perches from which they may scan the countryside for possible food or enemies. In such places they deposit body wastes with a high nitrogen content. The wastes accumulate in considerable quantities over long periods. Frequently such animal resting places become the habitat of particular lichens. The lichens may then be used as food by some rodent that enriches the meager soil of the site, to permit an even more luxurious growth.

The basic nature of underlying rock formations in a particular locality may determine the kinds of lichens to be found. Some lichens prosper on rocks in which lime is an important chemical. Others do well on rocks that are granitic in character, and are basically acid. Lichens may also play a part in controlling the erosion of soil particles by wind and flowing water. A lichen blanket over an accumulation of soil particles prevents, to a considerable degree, the displacement of the particles. Such soil anchorage stabilizes the soil and helps delay excessive water runoff, moderating stream volume.

Superior to most other plants in their ability to survive difficult conditions, the lichens may become the dominant, and perhaps the only, vegetation over great tracts of land. They may thus allow the existence of animal life—including human life—in the more desolate areas of the world. For example, the Laplanders are almost wholly dependent on lichens for their sustenance in an interesting and indirect way. The basis of the Lapp’s existence is the reindeer. Reindeer hides are used in making clothing and tents, the bones form implements, the flesh and milk are used as food. And the reindeer feeds almost exclusively on the lichens that cover that barren land both in summer and winter.

In the past, the Arctic has yielded an abundance of fur. Today, competition from substitutes has lessened the value of natural furs, but there are still many people in the world who derive a substantial part of their income from the sale of wild animal pelts. Few fur bearers eat lichens directly, but the fur bearers feed on lemmings and other rodents, which in turn feed largely on lichens. Even man makes use of some of the lichens, such as Iceland moss, as food, and others have been used as a survival ration for lost humans.

The Greek philosopher Theophrastus, who lived about three hundred years before Christ, wrote about old man’s beard lichen. In earlier days, the lichens were investigated more for their potential value as dyestuffs than for any other reason. Certain lichens have been used as a source of dyes for fabrics; but, unfortunately, the colors are not always permanent when exposed to light. Other lichens, in the genera of Roccella and Lecanora, yield archill, a dyestuff sometimes known as cudbear, that produces blue, red, and violet dyes that are used in medicines and drinks. Early botanists used the plants to illustrate to their students how inorganic rock could be turned to organic plant material.

Litmus, which turns red when exposed to acid and blue when exposed to alkali, comes from the lichens of the genera mentioned above. As a commercial substance,
litmus appears as a lumpy, blue mass, which is obtained from the lichens by exposing them to air in the presence of ammonia, potassium carbonate, and other chemicals. Litmus is used in chemistry as an index of acidity or alkalinity, and the proper use of soils, determined in part by litmus tests in which lichens are thus involved, is of great national economic importance.

Quite aside from the practical uses of the lichens, the plants appeal to man’s sense of beauty, and now and then to his superstition. In times past, it was the custom of medical men to assume that the dog lichen had value in the treatment of hydrophobia, because the spore-producing parts of the plant resembled a dog’s tooth. This, of course, would be considered ridiculous today. The little pixy cups that may be found at times scattered about on the surface of poor soils were reputed to have been the goblets used by the little people. Charlatans could always be found who would interpret the results of such meetings to the credulous—undoubtedly to the advantage of the interpreter. This was obviously pure fantasy, but perhaps fantasy had and still has its merit in a world dominated by grim reality.

The use of lichens as medicines has passed, for the most part, into limbo; but an old prescription for the use of Pelitgera in the treatment of mad-dog bite might be recited here. It reads: “Patient is bled and ordered to take a dose of Peltigera in warm milk for four successive mornings thereafter. He must take a cold bath every morning for a month, and for two weeks subsequent, a bath three times a week.”

In summary, it has been shown that there is a state of coexistence between two different kinds of plants—the algae and the naturally parasitic fungi—and that the condition is profitable to both the plants involved. Some botanists do not believe that this relationship is one of true coexistence, and claim with some basis in fact, that the relationship is rather one of mutual parasitism. Whatever the truth may be, however, the association is a workable one. In the past hundred years, we have undoubtedly gained more real understanding of the nature of lichens than we had acquired in the preceding twenty-three centuries. Who knows what the next century of study may bring in this wide field of investigation?
<table>
<thead>
<tr>
<th>VEGETATIVE PART OF PLANT</th>
<th>LICHEN REPRODUCTION</th>
</tr>
</thead>
</table>
| **Goblet or Pixy Cup Lichen**  
*Cladonia pyxidata*  

A mat of sod flakes, each to 1/5 inch long, rounded, lobed or simple; gray or to greenish brown. Flakes overlap to form essentially flat structure, but flake tips are free, are slightly raised, and may stand almost erect.  

**Green-gray or brown stalks arise from central part of flakes to 2/5 inch high, ending in goblet or cornucopia shape; or may be erect, strap-shaped, forked 1 to 3 times. Goblets may bear other goblets from rim; these in turn may bear similar goblets. Stalk hollow, with flaky surface that may shed portions.** |

| **Red Crest Lichen, British Soldiers**  
*Cladonia cristatella*  

Sod flakes, scattered or closely crowded, are greenish gray or straw-colored when dry, each to 1/5 inch long and wide, but often taller, its size or even less, with margins toothed or rarely lobed and divided. Is described as having a coral-like vegetative base.  

**Fructing branches to 1-inch tall and conspicuously coral-like, but often covered with sod flake scales. Sometimes three or four flake-like with radiating branches, uniting above to form a cup or tray. Surface smooth or wartly, greenish-gray, white, or slate-colored, with rind and variable branches.** |

| **Reindeer Moss**  
*Cladonia rangiferina*  

Appears shrubby with profuse branching. The basic initial thallus is rarely found or seen, being almost completely hidden by the tall branching tops of the stalks. Basic crust or sod flakes are like a gray granular crust lying close to the ground. This crust soon disappears as the tall structures develop.  

**Grows to 4 or more inches tall, with stalks to 1/10 inch in diameter but usually less, profusely branched. Tips commonly turn downward and are profusely and repeatedly subdivided. Surface like felt, but older stems may be mealy or powdery, ash-white or sometimes tinged by greenish straw color.** |

| **Pronged Easter Lichen**  
*Stereocaulon coralloides*  

A primary thallus is replaced by a profusely branched structure to 3 inches high. The basic thallus comparable to the sod flakes of the cladonias described, may disappear, but just where the one begins and the other ends is not well defined. Coral-like branches are slender, compressed cylinders.  

**Branches are smooth and naked in the lower areas, sea-green or ash, with a brownish cast. Surface appears warty and is spotted with very short-stemmed discs that are borne at or near the tips of the coral-like branching structures. These discs make up "cups" of previously considered species.** |

| **Old Man's Beard**  
*Usnea barbata*  

Vegetative structure is shrubby, frequently hangs from some support and is highly flexible. To 20 inches or more in length, covered with numerous radiating structures colored like main axis, and not always easily distinguished from the basic structure. Branches circular, finely roughened.  

**Basic structures may be a greenish gray that turns brownish or tinged with red. Commonly paler at the tips, becoming straw-colored there. Structures including algae and fungi may form soda on older tissues and be freed, forming new plants if they fall on territory suitable for development.** |

| **Long Beard Lichen**  
*Usnea longissima*  

Sometimes considered a subspecies of *U. barbata*. But *U. longissima* is longer, if relatively few, main branches. These are covered with branchlets that commonly radiate at right angles and are not usually tanged. Branchlets may be approximately 2/5 inch long.  

**The surface of branches is covered with finer at top and underlying materials. This surface may look scabby because of the covering scales. This species is considered here as an example of how variable these plants are and how close integrations may be found among otherwise recognizable entities.** |

| **Gold Eye Lichen**  
*Teloschistes chrysophthalmus*  

Highly variable. While *Usnea* has cylindrical branches, *Teloschistes* has flattened branches, and while the related *Ramalina* has branch tips that are blunt or pointed, in this genus the tips end in fine hairlike structures. *Ramalina* is also much smaller. Yellow to pale, greenish gray with yellow tinge.  

**May appear as hanging threads to 2 inches long, easily spotted because of yellow color. The algae are Protococcus, which appear as simple green spheres under the microscope. Plant seems to be profusely branched, but is more rigid than some close relatives.** |

| **Blister or Black-and-White Lichen**  
*Physconia leucomela*  

Surprisingly uniform, strap-shaped, irregularly forked strips, to 1/12 inch in diameter. Edges turn inward and downward and bear ragged looking, blackish hairs. Tips are much less blunt and are usually carried in dense tufts to nearly 1/5 inch across. Blackish hairs more or less opposite each other.  

**Upper surface is gray or whitish and undersurface is white, with some down on it, the white contrasting conspicuously with the black marginal hairs among which may be erect mounds of algae and fungi that may then be freed to establish new plants. Some species form flat rosettes rather than tufts.** |

| **Iceland Moss**  
*Cetraria islandica*  

Found in tufts or tangled masses to 2 or more inches high, with a pronounced tendency when drying to form something like a spine-edged trough. Sometimes found in paper-shin forked stalks to over 1/6 inch wide. All forms tend to curl when drying, giving them a highly variable appearance.  

**Surface is olive-green, but brown to gray when dry; it is commonly smooth but may be ridged or wrinkled. Under-surface is paler than the upper and may bear, near the branch bases, gray patches of soredia that serve a reproductive function independent of fruits.** |
### FUNGUS REPRODUCTION

<table>
<thead>
<tr>
<th>FRUITS BROWN OR PURPLE</th>
<th>WHERE FOUND</th>
<th>ECONOMIC VALUE</th>
</tr>
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<tbody>
<tr>
<td>Fruits brown or purplish, to 1/6 inch across, borne on tips of gobbets. Some relatives are stalked, or may be root- or scarlet stems. Fruiting structures, by the usual process, are not closely related to the gobbets.</td>
<td>Formed on ground, sod, logs, or rocks, and most abundant in regions of lime- stone rocks. Closely related to taller reindeer moss and the red crest lichen. Found frequently throughout the United States and with world-wide distribution.</td>
<td>Useful in furthering disintegration of rocks and soils, in anchoring loose particles from wind and water erosion, this helping to build up soil volume. Associated in folklore with pixies—mischievous sprites reputed to enjoy tea and cake. Very purplish fleshy parts. A most cosmopolitan plant, easily recognized.</td>
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</table>

### Fruiting bodies over swollen tips of branches, globular or lumpy, to 1/4 inch through. Usually scarlet, but may be maroon, black, buff, orange, or even white. Fruiting structures on practically every branch tip. Bright colors may attract insects, which may be instrumental in distribution of the spores. | Common in fields, woodlands, and along the roadsides on soil, rocks, tree bark, fence rails, and deadwood, but most frequently considered as being found on latter. Ranges throughout eastern United States, but apparently unknown in the American west or Europe, where C. bellatilora replaces it. | Of no major economic importance. Probably most easily recognized of all the cladonias. Serves as a soil-maker and anchor, and as slight flood deterrent. Most popular for transplanting to indoor terrariums. Name "British soldiers" doubles refers to apparent resemblance to red coats of soldiers. |

### Brownish fruits to 1/25 inch across appear as knobs on the tips of some of the fruiting branches. Tangled masses of whitish algae and fungal threads may be found in jumps along older stalks or may be incompletely scattered on feltlike surface. These may start new plants on suitable territory. | Found on thin layers of humus over rock surfaces in the open, under trees, or growing from rock crevices. Common under pines and other cone-bearing trees. It is widely distributed through North America, particularly in the north, and similarly distributed in Old World, often forming climax area. | Of considerable economic importance as basic food for reindeer and other animals of the habitat. Despite bitter taste, it may have some subsistence value as food for man, or as something to mix with sparse supply of flour to extend a diminishing food supply. May serve as Scandinavian famine food. |

### Discs, at first brown, surrounded by lighter or whitish area that becomes obscured with age. Algae are completely meshed in threads of the fungus. Unlike hollow stalk found in Cladonia, the stalk here is solid and not brittle. Possibly S. parschale with profuse branching is more representative. | Grows well on a thin humus layer over rocks. It is considered by some to be a subspecies of the common S. parschale, which has a wider distribution. This latter species is found from New England to South Carolina in mountainous areas, north through Canada and Alaska, Europe and Asia. | This lichen is of no particular economic importance. However, in the days when medicinal values were determined by the resemblance between plants and parts of the human anatomy it was believed that Usnea barbata yielded substances that stimulated growth of hair. |

### Fruits are seldom seen. They are usually small—up to 1/4 inch in diameter—and are distributed about the plant rather than at the tips. The fruiting disc is pale gray to buff and may have hairs drooping from its borders. Some close relatives have short, stiff, erect stems, while others are flexible. | Grows most commonly on tree bark or dry deadwood in mountainous forests. It is commonly associated with swamps, though actually it does not grow in the water itself. Grows on living or on dead plants and is found throughout North American continent and wherever conditions are suitable. | Probably of little if any economic importance as food for animals, let alone as fiber, or as a source of dye. Some day there may be a use for them in some way other than that of confounding botanists or of creating arguments among those working at classifying. |

### Fruiting structures are rarely found, but when present are near the tips rather than distant from them, as in Old Man's Beard. A related hairlike Usnias, has few secondary branches, and these are smooth rather than rough. Most lichens have subseptacular or variecolous as relatives. | Found hanging from trees and other supports in areas similar to those occupied by Old Man's Beard, especially in the northern United States. Some aspect of all these hanging lichens is affected by stiffness and position of the radiating hairs, by the disturbances caused by wind, and by character of supporting plant. | Of no generally recognized economic importance, and probably does no great damage to the trees on whose bark the patches are most likely to be found. Species growing on rock may well stimulate soil production through furthering disintegration of the rock. |

### Fruiting structures appear as stalked discs to 1/5 inch in diameter. Edges torn or toothed from which radiate finer hairlike structures, orange or conspicuously yellow. Undersurface is normally ash gray. Common name "gold eye" describes fruiting body. | Most commonly found on trees or old wood, and ranges in one form or another into all parts of North America as well as in the major continental areas of the world. Some related species, as T. partitius, are common on most stone walls and trees along water. | Apparently of no economic importance, and of interest to most people primarily because of unique and attractive color and the interesting structure of the plant parts that support the fruiting bodies. In spite of its wide distribution, it is not ordinarily as common as some other species. |

### Fruiting structures on short stalks are on branch tips. Disc-shaped, frosted gray, with ragged whitish rim, to 1/6 inch across, yielding brownish, 2-celled spores. Fruit production is rare in the northern part of this lichen's range. Borders of disc may be lobed. | Almost always found on trunks and branches of trees with some related species growing on soil and some on bare rocks. Closely related to taller reindeer moss and the red crest lichen. Common in the states of the southeast, yet grows as far north as central New York. Relatives range more to north. | Of no generally recognized economic importance in terms of value for direct consumption. Serves as useful fodder for wildlife and cattle and may even be eaten by man for its abundance of starch. May grow interspersed with patches of reindeer moss but is not easily confused with it. |

### Fruits are borne along the tip margins in discs to 2/5 inch across, with dark brown rims torn or spiny. The spores yielded from these areas are seen under the microscope as colorless and undivided. Fruits are not technologically fruiting bodies or spore-yielding parts of the fungus part of the lichen. | Found on rocks and soil in appropriate sites through northern United States and Canada, and throughout Alaska. Plentiful along coastal regions of New England, but to the south may be in isolated patches at higher elevations. Not easily confused with other lichens of its range and habitat. | Possibly our most important lichen in terms of value for direct consumption. Serves as useful fodder for wildlife and cattle and may even be eaten by man for its abundance of starch. May grow interspersed with patches of reindeer moss but is not easily confused with it. |
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<tbody>
<tr>
<td><strong>Letuce Lichen</strong></td>
<td>General color of plant is from pear to slate, with white to darker underparts. Attachments to support of plant are few or weak. Soredia, which yield combined algae and fungi, are not so conspicuous as the fruits that yield only fungus spores. A net pattern appears over the shiny green upper surface.</td>
</tr>
<tr>
<td><em>Cetraria lacunosa</em></td>
<td>Puffed tips an important characteristic to notice as this distinguishes plant from most <em>Parmelia</em> species. Upper surface is gray-green to yellow-green at border, but center may be olive-green to dull-gray and even black. Under surface of plant is chocolate, often turning black. The holdfasts are relatively few and are dark and rottikle. Soredia that yield algae and algae may appear in clumps.</td>
</tr>
<tr>
<td><strong>Puffed Shield Lichen</strong></td>
<td>Presence of true soredia is questioned by some authorities, while others claim they are found in a narrow white line that runs along the margins. In any case, both the nature and the presence of soredia are matters that must remain to be determined by further research.</td>
</tr>
<tr>
<td><em>Parmelia physodes</em></td>
<td>Upper surface is gray-green to yellow-green at border, but center may be olive-green to dull-gray and even black. Under surface of plant is chocolate, often turning black. The holdfasts are relatively few and are dark and rottikle. Soredia that yield algae and algae may appear in clumps.</td>
</tr>
<tr>
<td><strong>Stane-Raw Lichen</strong></td>
<td>Upper surface of lobes may be covered with fine white soredia that yield algae and fungi, the whole unit appearing either in white dots or with a whitish cast. Superficially, the shape of the whole plant has the appearance of liverwort, <em>Marchantia</em>.</td>
</tr>
<tr>
<td><em>Parmelia saxatilis</em></td>
<td>Soredia including algae and fungi are dusty-gray and appear along the lifted margins or along the ribs. The tissue is so thin that the undersurface may appear like the reverse of the upper surface so far as ridges and wrinkles are concerned, with grooves becoming ridges and pits becoming bumps.</td>
</tr>
<tr>
<td><strong>Boulder Lichen</strong></td>
<td>Upper surface has reddish-brown border that tends to roll upward showing the brown lobes in sharp contrast with the normal upper surface color. Black undersurface is smooth or delicately wrinkled. Lobes lack hairs on margins.</td>
</tr>
<tr>
<td><em>Parmelia conspersa</em></td>
<td>Upper surface of lobes may be covered with fine white soredia that yield algae and fungi, the whole unit appearing either in white dots or with a whitish cast. Superficially, the shape of the whole plant has the appearance of liverwort, <em>Marchantia</em>.</td>
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<td><strong>Broad Shield Lichen</strong></td>
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<td><em>Parmelia perlata</em></td>
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<tr>
<td><strong>Spreading Leather Lichen</strong></td>
<td>Upper surface of lobes may be covered with fine white soredia that yield algae and fungi, the whole unit appearing either in white dots or with a whitish cast. Superficially, the shape of the whole plant has the appearance of liverwort, <em>Marchantia</em>.</td>
</tr>
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<td><em>Sticta amplissima</em></td>
<td>Upper surface of lobes may be covered with fine white soredia that yield algae and fungi, the whole unit appearing either in white dots or with a whitish cast. Superficially, the shape of the whole plant has the appearance of liverwort, <em>Marchantia</em>.</td>
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<td><strong>Lung Lichen</strong></td>
<td>Upper surface of lobes may be covered with fine white soredia that yield algae and fungi, the whole unit appearing either in white dots or with a whitish cast. Superficially, the shape of the whole plant has the appearance of liverwort, <em>Marchantia</em>.</td>
</tr>
<tr>
<td><em>Sticta pulmonaria</em></td>
<td>Upper surface of lobes may be covered with fine white soredia that yield algae and fungi, the whole unit appearing either in white dots or with a whitish cast. Superficially, the shape of the whole plant has the appearance of liverwort, <em>Marchantia</em>.</td>
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<td><strong>Dog Lichen</strong></td>
<td>Upper surface of lobes may be covered with fine white soredia that yield algae and fungi, the whole unit appearing either in white dots or with a whitish cast. Superficially, the shape of the whole plant has the appearance of liverwort, <em>Marchantia</em>.</td>
</tr>
<tr>
<td><em>Peltigera canina</em></td>
<td>Upper surface of lobes may be covered with fine white soredia that yield algae and fungi, the whole unit appearing either in white dots or with a whitish cast. Superficially, the shape of the whole plant has the appearance of liverwort, <em>Marchantia</em>.</td>
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<tr>
<td><strong>Smooth Rock Truff</strong></td>
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<tr>
<td><em>Umbilicaria Dilleni</em></td>
<td>Upper surface of lobes may be covered with fine white soredia that yield algae and fungi, the whole unit appearing either in white dots or with a whitish cast. Superficially, the shape of the whole plant has the appearance of liverwort, <em>Marchantia</em>.</td>
</tr>
<tr>
<td>FUNGUS REPRODUCTION</td>
<td>WHERE FOUND</td>
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<tr>
<td>Brown fruits to 2/5 inch across arise frequently from margins of upper leaf surface. Some species have black or brown spores.</td>
<td>Commonly on tree trunks and twigs, most common in swamps. It is found throughout the mountainous parts of northern United States as well as in Alaska and Canada.</td>
</tr>
</tbody>
</table>
nature IN THE SCHOOL

The lichens are often found in schoolrooms and studied in school programs. They commonly appear in school terrariums, and are sometimes used to brighten up classroom corners. Outside the classroom, lichens may be discovered on the foundations of school buildings, on the bark of schoolyard trees, or on exposed stones in the school rock garden.

In developing a school or classroom terrarium that is to include some of the lichens, it is best to do some planning. For example, it would be well to include at least one lichen-covered stone as an example of the pioneering tendencies of the lichens in developing new territories; it will also serve to point up the part that lichens play in the prevention or delay of soil erosion, as mentioned in the accompanying article.

There is little point in trying to plant a lichen or lichens on bare stone, since success is not likely; and, of course, there is no point in asking a seed store for lichen “seeds.” Lichens do not produce seeds. However, it is fairly easy to establish lichens in a terrarium, since they have no true roots. The best way to transplant a lichen is to bring it to the terrarium on a piece of sod, in which plant adjustments have been made and can be examined.

Examine the list of eighteen lichens that accompanies this insert, and see how many of the plants can be collected and installed in your classroom terrarium. It is highly unlikely that a student could secure all of them; and even if he could, they would not all thrive in a single, small terrarium. Thus it might be worth while to have three or more terraria. One could be a “dry” terrarium, in which lichens of relatively dry habitat could be exhibited. A second might be a “wet” terrarium, for water-tolerant species. A third might be used to exhibit lichens that grow on the bark, twigs, or other parts of trees. In this latter might be included a small section of a lichen-covered fence rail or log. In any case, a record of the specimens’ original habitat should be kept, and an attempt should be made to duplicate as nearly as possible the conditions of water and light that obtained in the original locality.

It would be well to collect a few specimens for a herbarium, in order to supplement those of the terrarium. Most lichens lend themselves reasonably well to drying, but some have fine structures that are best preserved in a liquid. Highly diluted Formalin or somewhat diluted rubbing alcohol may answer this latter purpose. However, it should be kept in mind that alcohol may remove some of the coloring matter of a lichen, an important point where plant color is vital for identification.

It might be interesting to make miniature collections—not of whole lichen plants, but of units merely large enough to be easily identified. Such a collection might include some lichens found growing on tombstones in old cemeteries, with data indicating the possible age of the plants as deduced from dates on the headstones. It may be surprising to see how the lichens on tombstones that have been in place for a half-century or more differ from those that have been growing for a mere decade.

If a schoolyard tree exhibits lichens growing on its bark, it will prove interesting to drive in a row of small brads around the edge of the plants, taking care to see that none of the nailheads are covered by the lichens. Make a record of the date of the operation, and keep it in the schoolroom for future reference. During the following year, a new set of brads may be driven around the same lichen, and in this way the growth of the plant may be easily measured and recorded. If iron brads are used the first year and copper nails the second, it will be easier to distinguish the growth of the plant. You may find the growth rate a matter for surprise!

It might be interesting, also, to make some color sketches of various available lichens. The student might try to explain why the green areas of the plants are usually found exposed to the sun, while the white or black areas are not. He will notice, too, that the brilliantly colored parts of the lichens—like those of British sol-

Lichens may be transplanted to terrarium for close observation.
SKY REPORTER

Photography and spectroscopy help astronomers survey the sky

By Simone Daro Gossner

William Herschel's successors attempted to complete his survey of the heavens, extending it in particular to the Southern Hemisphere; but their studies did not in any way improve the model of the universe that he had derived from his own observations. This temporary halt in the progress of cosmology resulted mainly because no modifications or improvements had been brought to the design of telescopes since the days of Herschel.

The first half of the nineteenth century saw almost simultaneously the development of two techniques of observation: spectroscopy and photography. Some decades later, their application to astronomy would lead to the first modern concepts of the structure of the universe. To this day they are among the astronomer's most powerful tools.

Spectroscopy utilizes the fact that the atoms of a given element (hydrogen, oxygen, iron, etc.) emit light waves at certain frequencies only; this group of frequencies is different for each element and constitutes its spectrum.

Furthermore, the relative strength of the emission at the various frequencies of the spectrum is a clue to the physical conditions of the element (particularly its temperature). When light coming from a star or other celestial source is allowed to pass through a prism, it is dispersed like a rainbow according to the frequencies of the rays that comprise it. An analysis of this composite spectrum reveals the physical characteristics of the source.

The invention of photography, by Daguerre in 1839, was not immediately applicable to astronomical research, because the early photographic plates were too slow to produce usable pictures of sky objects. When the first photograph of the moon was obtained, in 1840, it seemed a miracle that the image could be recognized at all. But with the gradual improvement in photographic plates, the astronomical advantages of this new process became readily apparent. The photographic process is a cumulative one; as the exposure time is increased, images build up, reveal-
ing progressively fainter objects and finer details. The human eye does not possess this capacity; no matter how long one looks at a star through a telescope, it will always have the same brightness. Therefore, astronomical photography is capable of recording celestial objects too faint to be observed visually with any instrument.

By the end of the nineteenth century, photography had become a powerful adjunct to astronomical research. Many existing visual telescopes were adapted to photographic use, and new ones were designed to serve exclusively as cameras. The optical system of the telescope (whether mirrors or lenses) plays the role of the lens in a conventional camera, and focuses the image on a photographic plate. Film is seldom used because it tends to shrink irregularly and is not very durable; a glass plate coated with photographic emulsion is usually preferred.

The most powerful photographic telescopes in existence today fall generally into two categories. Large parabolic reflectors permit the observation of extremely faint and remote objects, but cover only a very small area of the sky at a time. So-called Schmidt telescopes, consisting of a spherical mirror and a correcting lens, offer the advantage of a wide usable field. This wide-field characteristic makes them ideally suited for extensive sky surveys.

Less than a century ago, nebulae and star clusters were known to astronomers as hazy patches in the sky, with ill-defined outlines and barely distinguishable structure. Except for a few loose clusters of stars, it was generally impossible to determine whether the object under scrutiny was a stellar aggregate or an amorphous mass of nebulosity. The suggestion by Immanuel Kant and a few followers that some of these objects might be "island-universes" belonged strictly to the realm of speculation.

By contrast, observations with the large photographic telescopes have not only confirmed Kant's assumptions, but also have revealed the incredible variety in the shape, structure, and composition of the nebulae. On the other hand, powerful spectrographs attached to modern telescopes have made it possible to distinguish between true gaseous nebulae and remote stellar systems.

Gaseous nebulae are found almost exclusively along the broad band of the Milky Way, and arise in most cases from the presence of vast amounts of interstellar gas (mostly hydrogen) and dust particles. When stars are embedded within this material, the loose particles act as billions of tiny mirrors, reflecting the starlight in every direction. In the embedded stars are unusually hot, the surrounding material is rendered self-luminous, that is, it emits its own light. One of the most famous emission nebulae of this kind is the Great Nebula in Orion (see picture on p. 45), which may be seen with the naked eye, dimly surrounding one of the stars in Orion's sword. If, on the contrary, there are no stars within the nebula, it may still be visible as a dark mass if it happens to be superposed against the background of a more distant reflection or emission nebula (see Horse head, at right, below).

A distinct category of emission nebulae comprises small tenuous, shell-like objects, each deriving its illumination from a very bright central star. These gaseous shells are known to exhibit turbulent motions. When viewed through a small telescope, they appear not unlike the planets Uranus and Neptune; this fact has earned them the name of planetary nebulae (see Dumbbell, at right, above). About 75 of these planeraries are known at present.

Some of the objects, which had been classified as nebulae in earlier days, proved to be vast stellar systems, not unlike our own Milky Way, but so distant that it had been impossible to see their individual stars. To distinguish them from true nebulae they are called galaxies (from the Greek galaxies, milky), but the designations "nebula" and "extragalactic nebula" are still encountered in astronomical literature. Galaxies often exhibit a characteristic spiral shape (see Messier 33, at left, above) with enormous arms winding around a bright nucleus of tightly packed stars. Other are more nearly elliptical, or frankly irregular. The shapes seem to be directly related to the composition of the galaxies. Very hot stars and associated interstellar ma
sight, making it hard to ascertain its form. Galaxy is in Coma Berenices.

The Dumbbell Nebula, a planetary nebula, represents a gaseous shell illuminated by a very bright central star. About 750 such planetary nebulae are known.

The Horsehead Nebula, a star-free cloud of gas and dust particles, appears as dark mass before lighter background.

...
THE SKY IN NOVEMBER

From the Almanac:
- New Moon: November 3, 4:59 A.M., EST
- First Quarter: November 15, 7:13 A.M., EST
- Full Moon: November 22, 4:44 A.M., EST
- Last Quarter: November 30, 1:19 A.M., EST

For the visual observer:
Mercury, in the morning sky, will reach its greatest western elongation on November 7. Some 19° west of the sun that day, it will rise about an hour and three-quarters before sunrise and it will be found very close to the planet Venus. It will be favorably placed for observation during the first half of November, rising one and a quarter hours before the sun on November 1, one and a half hours before the sun on November 15.

Venus, also a morning star, will rise at approximately 4:45 A.M., local standard time, on November 1, 5:15 A.M. on November 15, and 5:45 A.M. on November 30. It will be low in the southeastern sky shortly before sunrise.

Mars, in the evening sky, will be too close to the sun to be observed conveniently.

Jupiter, in Capricornus (−1.7 magnitude) will be low in the south at sunset. The planet will set in the southwest at approximately 10:15 P.M. on November 1, 9:30 P.M. on November 15, and 8:45 P.M. on November 30.

Saturn (+0.3 magnitude) will be in Sagittarius, approximately 5° west of Jupiter and will set about forty-five minutes before that planet.

Two meteor showers may be expected in the course of the month: the Taurids on November 5 and the Leonids on November 16. Both have an estimated maximum of fifteen meteors per hour for a single observer.

Elongations of Mercury and Venus:
Because Mercury and Venus have smaller orbits than that of the earth, they are never seen very far from the sun. To a terrestrial observer, they seem to oscillate between two extreme positions on either side (east and west) of the sun. Astronomers use the term elongation to designate the angular distance in longitude between the sun and a planet; accordingly, the expression “greatest elongation” is applied to these extreme positions.

Since planetary orbits are not perfectly circular, successive greatest elongations have a slightly different angular extent, depending on the orbit’s orientation in the line of sight. This effect is particularly noticeable for Mercury, whose greatest elongation varies from 13° when the planet is at perihelion (the point in its orbit closest to the sun) to 28° at aphelion (the point in its orbit farthest from the sun). In the case of Venus, the greatest elongation of the planet’s orbit has been found never to exceed 48°.

Greatest elongations of Mercury are not all equally favorable for observation. The planet moves very nearly along the great circle of the ecliptic—the apparent path of the sun among the stars—and it is most readily observed when the ecliptic is most tilted to the horizon. At our latitudes, this condition is fulfilled in the spring for the evening sky and in the fall for the morning sky. Observations of Mercury should, therefore, be scheduled accordingly.

On the preceding pages, Mrs. Goosner offers the ninth in her 1961 series on the growth of cosmological concepts.
MAGNITUDE SCALE

-0.1 and brighter
+0.0 to +0.9
+1.0 to +1.9
+2.0 to +2.9
+3.0 to +3.9
+4.0 and fainter

TIMETABLE
November 1 10:00 p.m.
November 15 9:00 p.m.
November 30 8:00 p.m.
(Local Standard Time)
The Male Spider

Myth wrongly labels him few in numbers and sorry in prospects

By Theodore Savory

In thousands of homes across the land this fall, a standard scene will be played. A large, long-legged spider will scurry rapidly across the living room floor and disappear under the piano or behind a sofa. A woman will shriek, or nearly, and demand that the man of the house find and kill the lurking creature. The peace of the fireside will remain disturbed until an entirely harmless arachnid has been driven from hiding with umbrella or broomstick, trapped in a nimmer, and flung outdoors or mercilessly committed to the flames.

This is not the place to examine the irrational fear that the luckless animal has aroused by its unexpected arrival. But when calm is restored, it is interesting to observe that almost no one out of the human cast of thousands will have noticed these facts: the season is autumn, the time is evening, and the spider is (or was) a male of the genus Tegenaria, one of the fairly common house spiders.

Among the first notions that a student of spiders acquires are these traditional ones: that male spiders are rare, that they do not spin webs, and that they are eaten by their mates. All three notions, as we shall see, are false in whole or in part. Collecting in woods and fields seems to confirm the males' apparent rarity and so, perhaps, excuses belief in the other two notions. Male spiders certainly are peculiar; there cannot be many animals among the invertebrates in which the attainment of maturity is accompanied by so great a change in the behavior of the sex.

What are the outward and visible signs that show a spider to be a male? In nearly all male animals, the testes—the glands that secrete spermatozoa—are directly connected by two ducts called the vasa deferentia to an organ that either ejects the sperm into the water over newly laid eggs (as in many fishes), or transfers it to the body of the female. The testes of a male spider occupy a normal position in the abdomen, and the vasa deferentia open at an inconspicuous orifice just behind the waist. But the spider's two intromittent organs are nowhere in the neighborhood. They are found, instead, at the ends of the pedipalpi—a pair of leglike limbs arising from the sides of the spider's mouth and in front of its first pair of legs. In female and young male spiders, these pedipalpi are tactile organs, freely supplied with sensory hairs. But when the male matures, the last segments completely change their appearance. This change has already begun at the time the male undergoes its next to last casting-off of the skin. Then the palp can be seen to be swelling at their tips. This is due to the matura tion of the male organs; they will appear fully developed when the skin is cast for the last time. The palps' last segment, which in its early developmental stages resembles a finger and later looks like a thumb with a single, terminal claw, has now become a hollowed, spoonlike container. The claw has disappeared or has been converted into part of the elaborate apparatus forming the spoon.

So much for the first traditional notion—the apparent rarity of male spiders. During more than three quarters of their lives, males cannot be distinguished at sight from their sisters. Their palps resemble those of the opposite sex and, since there is no difference between male and female activities, one naturally, if unthinkingl y, tends to look upon all such immature forms as females. In fact, however, half of these supposed female males are unannounced males.

In the past, several authors believed that they had found secondary differences that enabled them to separate the spiders according to their sex as far back as the egg stage, but these secondary signs are now discredited. Investigators who have raised spiders from cocoon to old age have found that the proportions of the two sexes are about equal.

Why, then, are mature male spiders rare? During recent years, I have made it a practice to keep in captivity (and to watch with special care and interest) any sub-adult males of the genus Tegenaria that have been able to find. It was my hope to detect any male change from "female" behavior that might occur at this stage of approaching maturity. The results have been negative. When put into cages, these sub-adult males spin normal webs, eat the flies with which they are supplied, feed with the usual greed if given the opportunity, and in no way support the dictum that coming events cast their shadows. Finally they molt.

At this point, another traditional notion must be revised. It is true that if nature males are kept in cages for some time, their webs fall into disrepair; evidently the webs are not receiving the nightly quota of added silk that formerly restored the ravages of the chase. But this is not apparent at once. If an adult male Tegenaria, which has just molted for the last time, is put into a new cage, it will spin a web and feed on flies, continuing for perhaps ten days or a fortnight to lead the same old life. Then a moment comes when it takes a first step toward achieving its male function.

The spoonlike palpal organs, which have already been described, are now complete, but they contain no sperm. It is obvious that the palps should now be swung round into contact with the sperm-emitting orifice in the spider's abdomen, and so receive a charge of semen. It is obvious, except for one thing: the palps are too short—the orifice is beyond their reach.

The male spider overcomes this difficulty by spinning a small, special web called a sperm-web, depositing a drop of semen thereon, and then immediately applying the palps to that drop. They take up the fluid as would a syringe. This remarkable pro-
The sperm-web is usually triangular or rectangular in shape and is spun in an inclined or almost vertical plane. When it has been made, the spider shakes or rubs his abdomen upon it, depositing a drop of seminal fluid, and into this drop the palps are inserted, usually in turn but exceptionally together; the fluid is drawn up by surface tension. The whole process takes from five to twenty-five minutes.

With its palpal organs fully charged, the male *Tegenaria* begins a wandering life, in which it seems to be more highly sensitive to environmental detail than before. Perhaps this increased perception is a result of the humid state of the palps; perhaps hormones are responsible. Driven by whatever stimulus, the male wanders abroad, seeking it knows not what.

How far must our *Tegenaria* go? How far can it go? Calculation will answer the first question, for the average distance to be covered by any male wandering at random can be determined—given, first, the lengths of its legs; secondly, the diameter of the female web with which the legs must come into contact; and thirdly, the population density of the species. To clarify the mechanics of this phenomenon, it should be mentioned that the sense organs on the tips of the males' legs inform them when they have stumbled onto a female's web. And since a spider walks with its legs more or less parallel to the ground, spiders with longer legs cover a greater area as they move. Likewise, a larger web is more apt to be chanced upon than is a smaller one. (The situation is like that of ice floes drifting on the Arctic Sea: their areas affect their chances of touching one another.)

The whole matter is further complicated by the fact that, among some species, both sexes are wanderers, while among others only the male wanders, in search of the female's web.

The *Tegenaria*, with which we are concerned, belongs to the second of
these categories, and the distance a male of this type of spider would have to walk before first meeting a female's web is expressed by this formula:

\[
\text{Average Distance} = \frac{a}{(d + s) \times n}
\]

Without getting involved here in the mathematics by which such a formula for random wandering is arrived at, we may apply this one by substituting the area of the spiders' immediate habitat for "a," while "d" is equal to the diameter of the female's web, "s" is equal to the over-all spread of the male's legs, and "n" equals the number of webs of the particular species' females in the given area.

If it is assumed that the male has legs one inch long, giving a span of two inches from side to side, that the female's web has a diameter of twelve inches, and that there is one such web in a cellar that measures 21 feet by 15 feet, then the male spider may expect to have to walk 90 yards before coming upon a web. If there are two webs, he walks only half the distance; if three webs, then he walks one-third the distance, and so on.

To these cold figures must be added the information that the number of spiders of all species per acre is not likely to be one or even a hundred, but may reach a total of more than two million. Even if only a small proportion of this population can satisfy the needs of one wanderer, it seems unlikely that any male spider runs much risk of bachelorhood.

How far the male can go is, in my opinion, more important than how far he must go. Even if a male spider has to walk only fifty yards, it is likely to be wearied by the effort. It is a member of a sedentary, not a vagrant, species; the thoracic muscles, which have to move its eight long legs, are very small. Data on this question, however, are lacking. We know only that the wanderer never rests, but perseveres until the sense organs of the foot report it is treading on the web of its future mate.

Immediately the male's behavior changes. Now begins a series of sometimes prolonged preliminaries, which delay the transfer of the sperm. These actions have been fully described for very many different species under the unfortunately anthropomorphic name of "courtship." A few remarks on spider courtship are therefore pertinent.
First, we need intensive study of the courtship patterns of single species, so individual variations can be eliminated and the really essential details retained. It is among such species-predictable details that the most effective stimuli and appropriate responses will be found.

Again, we must know the effects on courtship of the conditions of the spiders themselves. We need comparisons between a recently molted male and one that has been mature a week or more before being allowed upon a female’s web. Similarly, we require comparisons between the reactions and receptions of recently matured and long-matured females. We must contrast hungry with well-fed spiders of either sex. This has not yet been done in sufficient detail.

Third, in all published descriptions of spiders’ courtship it is the male that steals the limelight. We are told of everything the male does; yet the female is also receiving stimuli, and it is unlikely that she does not react at all. A little attention directed toward the female partner in these rites might be well rewarded.

Traditionally, accounts of courtship in spiders have been badly distorted by the myth that the female will inevitably kill and eat the male, and that the ritual of courtship is designed to prevent this. It is seldom pointed out that there are species of flies where the male, like the spider, will pay court by posturing and leg-waving in front of the female; or that the male of at least one species of fly offers a morsel of food to the female, as does the more widely known spider Pisaura. Such flies are carnivorous, but not so cannibalistic that the male needs this protection. The “insurance-policy” theory of courtship, in my view, is no more valid for explaining spiders’ behavior than it is for explaining flies’ behavior.

One of my most revealing glimpses of the living spider in nature was given me one afternoon in the fields of Herefordshire, when I saw a male Lycosa lugubris walking across the trunk of a fallen tree. It was the only spider in sight at the moment, but suddenly it stopped and, without apparent reason, began its courtship actions. It continued to raise and lower its palps for perhaps half a minute, and very absurd it looked, all alone on the broad expanse of wood, energetically courtling nothing. Perhaps this instance supports the hypothesis of the occurrence of what Konrad Lorenz has called “vacuum activity.” The internal drive or urge may have reached such intensity that a set of reactions, which would normally appear as courtship movements only when the correct stimulus was present, broke through the male’s neuromuscular controls and took place in the female’s absence. It was an abnormal but illuminating event.

From it, we could go on to build up a picture of the male spider, under compulsion from internal stimuli, responding to a combination of external stimuli that leads to its peculiar pattern of courtship. This would bring the spiders’ courtship into line with observations and conclusions on other kinds of behavior seen among animals of many different kinds. In this connection, it is reasonable to suppose that a special combination of stimuli is necessary to induce an act that characterizes the species and which may be performed only once in a lifetime. But it is far less reasonable to picture the courting male as precariously poised in an anthropomorphic fashion, torn between desire and fear. Actually, he has been driven (or guided) by the inexorable accident of statistical probability into a situation toward which his whole existence has been directed, and in which the noble female is to be the essential stimulus.

For Tegenaria, courtship is a relatively simple process. The male drums on the web with its pedipalpi in a very characteristic way; the vibrations thus set up reach the female, for whom they possess a very different significance from that of the vibrations of a fly in these same meshes. The female does not rush out to the kill; instead, the male, drumming unceasingly, slowly approaches the female.

An aspect of the male spider’s behavior that has not hitherto been sufficiently stressed is this: the search, the courtship, and the mating have been three successive and increasingly strenuous activities. Sometimes the search has been so tiring that the courtship is imperfectly performed; sometimes the courtship is so strenuous that the male cannot finish it; finally, there is at least one case on record in which the wearied male died during mating. Hence the third of our traditional notions.

Even when it does not die, the fulfillment of its function in continuing the species leaves the male spider without purpose. Biologically, no great extension of its life can be justified: in fact, it is clear that the animal is exhausted—“run out,” as the gamekeeper says of his stags. At the end of their rut, however, the stags at least can rest, feed, and regain strength: male spiders cannot. With the coming of maturity, they have forsaken their webs to go a-wooing, sacrificed their chances of ever catching another fly, and condemned themselves to starvation.

My observations carry the story further: on the basis of these, I believe that male spiders are never very robust. Far from being full of the virility that the stories of their dances suggest, far from showing an enhanced activity from “the greater metabolism of the male” mentioned in textbooks, the males are weaklings, clinging to lives that seem to have one object.

In September, 1953, I had a mature male Tegenaria, apparently in the best of health, living in a box in a good web of its own making. I put a vigorous fly into the box as a meal for the spider, but the insect was too strong to be entrapped by the web. Time and again, the spider rushed out to the source of disturbance of the silk, but always the fly escaped and the spider returned to its resting place. A few hours of this were more than the spider could support. The shaking of its web gave it no rest; it was compelled to run out to the stimulus again and again until, completely exhausted, it died.

We can conclude, then, that the death of the male spider is due to its constitutional weakness and not, as is usually thought, to its mate’s cannibalism. But if, as we have seen, the male does not correspond to the traditional image we have of it, investigation has not made this animal much less puzzling. It has, instead, hinted to us what the actual puzzles may be.

Climax in male’s life comes as, palps charged, he comes upon female’s web, begins to vibrate it in distinctive way that signals preliminaries of courtship.
Part II

People of Baltistan

Agriculture, herding, and dairy farming form the basis of the local economy.
During the two centuries that the British stayed in India, they penetrated into nearly every corner of the country and found out almost all there was to know about it. This was not only because of British administrative and security needs, but also because of a national penchant for adventure—combined, in many cases, with a taste for scholarly endeavor and interest in the culture. Thus was produced a wealth of factual and descriptive books that will long remain a monument to British rule in India. The "District Gazetteers," in particular, are exemplary, for they relate in minute detail all that was known at the time about the people of a given district—their history, ethnology, language, folklore, and economy.

But for Baltistan there were no "District Gazetteers." since the country was both distant and under another administration, that of the Maharaja of Kashmir. The British did not extend their rule into north India until the middle of the nineteenth century, and for various reasons, including administrative expedience, they left Kashmir and its several far-flung districts in the hands of a Hindu soldier-prince. Although British officials were stationed in Kashmir during the next hundred years, there were few of them, and they generally served as "advisers." Their numbers grew, however, during times of military or political tension.

Because Kashmir occupied a strategic position at India's juncture with China, Russia, and Tibet, and because the maintenance of cordial relations with the ruling prince was important to the regime at Delhi, it was necessary to obtain permits to visit the area. This was only a formality in the case of Srinagar and the Kashmir Valley, but it took on real meaning as applied to such frontier areas as Baltistan and Ladakh. However, when it became known that the hunting was excellent and that prize ibex heads were to be had in the faraway Karakorams, red tape disappeared in the face of attacks from that formidable breed known as the "British sportsman." And so the region was "discovered."

In the latter nineteenth century, Sir Francis Younghusband's daring trip from Peking across the Gobi Desert and into India over the Muztagh Pass excited world interest in the Karakorams. Soon after that, the great scientific and mountaineering expeditions began to arrive. The first, in 1902, was mainly British, led by Sir William Conway. The expedition penetrated to the Baltoro Glacier, one of the longest glaciers in the world outside of polar regions. The members mapped much of the tributary glacier system and climbed several peaks.

Between 1899 and 1912, Mrs. Fanny Bullock Workman, an American, and her husband, Dr. William Hunter Workman, conducted five expeditions to Baltistan and the Karakorams. Other major scientific and mountaineering expeditions in the early years of this century were those of the Duke of the Abruzzi, 1907-08, and of au-
Boatmen prepare to ferry passengers across Shyok River at Khapalu. Conic grass baskets on villagers' backs are made in accord with the size of user.

other Italian, Dr. Filippo de Filippi, in 1913-14. The territory covered by both expeditions overlapped the Karakorams (i.e., Baltistan) and Chinese Turkestan. In 1923-24, the Americans Katherine and Robert LeMoyne Barrett spent a year trekking and climbing in Baltistan and Ladakh. Since then, and particularly in the last ten years, the Karakorams have become an international mountaineering playground. Each year from two to four expeditions contend for the honor of reaching the tops of perhaps a score of unclimbed peaks over 20,000 feet. Americans have had a good share in the conquests of some of them, including Hidden Peak and Masherbrum, and have acquitted themselves well on the 28,250-foot K-2, the second highest mountain in the world, after Everest.

What is Baltistan like and how do one reach it? These questions are asked even in Pakistan, for few Pakistanis have had the opportunity to perhaps desire to go there. The usual tendency is to confuse Baltistan with Baluchistan, one of Pakistan's provinces to the southwest. Yet the area, within ninety minutes' flying time from Rawalpindi, Pakistan's capital, is exciting enough to thrill the most sophisticated traveler. The plane ride (the alternative is a twenty-day mule track over the hundred and forbidding Deosai Plateau) is exciting enough to thrill the most sophisticated traveler. The plane skims just above successively rising ranges of peaks, and skirts the northwestern side of sprawling, snow- and ice-capped Nanga Parbat, called the "Germ killer" for the twenty-six Germans and porters killed on it in the 1930s. Shortly before arriving at Skardu, the plane sweeps into the Indus Gorge, whose walls often seem to hem it in on three sides. Skimming close above a last, high buttress, the plane lands on Skardu's baked mud field.

Skardu is the administrative and trading center of Baltistan, and it here that one finds the greatest diversity of races and tongues. In the bazaar, Uigur-speaking Turks from Kashgar, Pushtoons from Peshaw...
In numerous small tea shops one hears some of the dialects and tongues that illustrate the different streams of humanity now comprising Skardu’s population: Burushaski from Hunza, Shina from Gilgit, Khowar from Chitralt, and sometimes Sindhi or Bengali.

This linguistic mélange has affected the local language, and pure Balti is hardly spoken in Skardu anymore. The local patois is such a mixture of Urdu, Balti, Hindi, and Persian that the Balti from other villages say it is hardly understandable. For trading and administrative purposes, Urdu (one of the official languages of Pakistan) is the lingua franca.

The populated part of Baltistan, which lies on the southern and western flanks of the Great Karakoram chain, is made up of a number of valleys. The first of these valleys is that of the great Indus River, running northwest from its source in Tibet, and the rest are those of tributary rivers, such as the Shyok and Shigar, and a number of lesser, glacier-fed streams—the Hushe, Thalhe, Braldu, and Basha. From at least the time of the Moslem conversion, local rulers have presided over seven of these valleys or valley sections: Skardu, Khapalu, Shigar, Rondu, Kires, Kharmang, and Tolti. From time to time, other principalities have risen but have usually been short-lived. As far back as is known, these local rulers—called variously rgyalpo, tham, sultan and raja—have been fighting among themselves. Only in a few instances has a leader arisen influential enough to unite them all—Ali Sher Khan Anchan of Skardu and Ali Mir of Khapalu (and these two are possibly the same person) are the main ones. But generally the raja of Skardu has enjoyed a traditional position of pre-eminence, perhaps because Skardu has always been, as far as we know, Baltistan’s trade center.
With the return of the Hindus to Kashmir in 1847, local rajas were stripped of forts and military power and reduced to the status of jagirdars (estate holders). To keep them peaceful and reasonably content, they were given privileges such as subsidies, tax exemptions, and rights of revenue collection according to their former importance, degree of resistance—or help—to the invading forces, as well as their current behavior.

The traditional class structure of the Balti, still observed in name but divested of most of its earlier importance, had, at the top, a raja (cho) class, followed by a wazir (minister) class. Membership in the latter carried varying status, depending upon the number of wazirs a particular raja had in his retinue. After these came the kacho group, or relatives of the raja. Included in this category were children born to a raja’s “ordinary Balti” wives or concubines, who came from non-raja families. Such children were not eligible for succession to the rajaship. Next came the patho (or “milk-mother”) families, whose mothers had suckled a young raja (this practice continues today). At the bottom of society stood the mon, a caste of musicians. Another group holding some special status was the jacho—members of families who had come to Baltistan in the retinue of a future rani (wife of a raja) from the ruling families of the adjacent states of Hunza or Nagar. And yet another was the bu manner—those who had accompanied a future rani from the ruling family of Ladakh. Membership in these groups was hereditary, although the wazir class tended to be somewhat transitory, the post originally having been appointive and therefore subject to the political whims of the raja.

The climate of Baltistan is extremely arid—less than six inches of rainfall a year. Since the economy is mainly agricultural, irrigation poses a considerable problem. Despite the fact that running water is the most characteristic sound in Baltistan, the problem of how to raise water to the flat, cultivable spots that often lie hundreds of feet above glacier torrents is a knotty one. The Balti solution has been to construct rather amazing complexes of take-off canals, aqueducts, channels, ditches, and rivulets, which they direct with consummate skill through innumerable layers of neat terraces. The water flow is controlled by mutual consent, each group of fields being allocated a certain day each time during which the water flows.

During the British period, the Balti were famed in India as road-builders. This was probably in part the result of practice they had building take-off channels. The channels are often not more than a mile long and sometimes have to be built across precipitous rock faces and perilous avalanche slopes. Many a Balti has been killed while building one. Sometimes the water flow is carried in hollowed logs perched on wooden stilts or timber jammed into a crack, but more often they run on elaborate masonry foundations built out gradually from the wall below. The longest one, Skardu, constructed of massive granite blocks, stretches some three miles and in its last reaches consists of a canal raised some fifteen to twenty feet above ground level. Tradition has it that it was built by order of the local Buddhist Queen of Skardu, Mendo Gyalmo, about five centuries ago. No one knows how the blocks were moved.

A typical Balti village can be described best as an oasis. To appreciate this, it is necessary to contrast village sites with valleys. The valleys are invariably barren and formidable, with rock and shale escarpments sweeping...
Wooden shrine, *astana*, marks grave of a holy man. Style of architecture may be a carry-over from Buddhist period.

A dozen *zhos*, or yaks, is considered extremely well off. The *zhos*—particularly adapted to Balti conditions—is a cross between the yak and the cow. The yak is unable to withstand the summer heat of the valleys, whereas the ordinary cow cannot tolerate the altitude of the upland pastures. The *zhos* has a high milk yield. Since there are usually no grazing grounds near the villages, all livestock must be brought to upland meadows called *broks*. In late April, as soon as the snow begins to melt, village men and boys start moving the stock, often following the receding snow line to as high as 14,000 feet. Later, the women and girls take over while the men descend to tend the crops. Periodic trips are made to the village in summer to bring down a little ghee and curd, the bulk of which is stored in skins for consumption during the winter.

During the winter, the sheep, *zhos*, and other livestock move in with the family—usually on the underground floor of the house—and man and beast apparently keep warm together. The livestock are fed mulberry leaves, inner bark, barley straw, and dried turnips during this period.

Communication between villages and hamlets is often difficult, depend-
Tossing grain in air, a Balti farmer winnows crop in Shigar Valley. Breeze separates chaff from the kernels of grain by blowing it away to the side.

Driven in circle, zhos thresh grain in the Hushe Valley, an area noted in Baltistan for its wheat. The zho is a cross between the yak and common cow.

ing on the season. In summer, when glaciers melt, it is virtually impossible to cross the raging torrents that are little more than gentle mountain streams at other times of the year. Various types of bridges have been constructed by the Balti to overcome this. One of them is the rope bridge. Made of woven branches, it is mainly to span the larger rivers, including the Indus. Crossing one for the first time is an experience not soon forgotten. The trickiest part occurs in the middle of the bridge, where one must climb over or under a stick held apart the two handrails; the choice poses a dilemma since the height of the stick makes either move awkward.

In the valleys that have sizable perennial streams, crude but sturdy woven bridges on the cantilever principle have been built at important crossings. They consist of one arch, whose s
sorting timbers project over other timbers leading from the bank. The
horses are weighted with masonry. Where the valley widens and the
reshet divides into small channels, local villagers merely bridge them
with crudely hewn planks or logs. To my mind, crossing these is a harrow-
ing experience, for some are twenty to twenty-five feet long and have
a most unpleasant tendency to limber
ness in the middle. The combination of
up and down motion with the illusion
of sideward movement from looking at
the rushing water is unsettling.
Probably the most enjoyable mode
of travel in Baltistan is by zak (raft),
stick frame lashed onto two dozen or
more inflated goatskins. Zaks are used

Balti reaps grain near Kharmang, in
Indus Valley. Surplus may be bartered.
only on the larger rivers, such as the Indus, Shyok, and Shigar, where there are sizable stretches of relatively calm water. But in the hands of four expert polemen these craft can negotiate even foaming rapids.

The only other means of travel in Baltistan are feet—human and equine, the former being the most common. It is not unusual to see dozens of men plodding barefoot into Skardu with loads of more than 100 pounds on their backs, having come as far as 30 to 90 miles. The postal system provides another graphic example of foot travel. Each runner carries the mail for a four-mile stretch—the *dak*, by which the Balti also measure distance. They may be seen day and night, scurrying along valley tracks, their odd, characteristic, fast shuffle-step eating up one *dak* in about an hour. Occasionally, a horse is available for transport, but there are few valleys into which safe pony tracks have yet penetrated. On the whole, horses in Baltistan are more for prestige than for travel but, above all, are for polo.

**Polo** is the national game of Baltistan and the Balti claim it was theirs first. The Balti word for ball is *polo*, and the Chinese used to call the Balti *Po-litu* or *Po-lu-lo*. The Gilgitis still call them *Paloyu*. Is this mere coincidence or does it indicate that the Balti claim of inventing the game has validity? No one seems to know. This is one more of the many questions about this remote, little-known country that awaits systematic study by ethnologist, archeologist, and historian.

Because a casual visitor to Baltistan cannot hope to present a detailed account of a typical day in the life of a villager I have asked Rev. Alfred F. C. Read, an authority on Baltistan, to provide the following description. Mr. Read, author of *Balti Grammar*, acquired an intimate knowledge of Baltistan during more than a decade as a missionary there.

"Shortly before the morning star of autumn begins to dim and the black sky pales slightly, a wooden door creaks on its pivots—it has no hinges—as a Balti leaves his house. He goes to the little village stream to wash, then crosses the dusty field and enters the verandah of the miniature mosque, where he has the task of calling the faithful to the dawn prayer. As his cry in uncertain Arabic echoes along the narrow valley, it seems to stimulate a score of cocks to crow.

"The folk of this valley are Islam. Abdul Kareem is their akhoond I common consent rather than by ordination. He spent a year or two at a local primary school but his attainments are mainly the ability to decipher and intone correctly the verses of the Arabic Koran. For some years now he has had the privilege of leadership in the tiny hamlet of six huts of various shapes, sizes, and state of disrepair. He performs marriage prayers over the dead, and recites the Koran into the ears of the newborn.

"By the time the sun lighted t
People of country upper peaks, everyone is awake because there is much to be done. The morning meal will come later, about no'clock, but for the moment a hasty lunch suffices—a handful of yos parched grain and roasted apricot kernels or a drink of stewed apricot juice, anything that is handy. It is only khabar (literally, 'push into the mouth'). An appetite will come later.

Toothless Api (grandmother) is already carding a pile of Tibetan wool bought recently from the Buddhists up the valley. Old Ali, tall and rather distinguished, is busy, too, for he has an appointment to sample a strain of tobacco in the next village. Ahmad and Marjan are finishing sets of homemade sandals, for they are setting out on the long road to India before the passes close. Money can be earned in faraway India, and on return a few extras can be bought for the home: perhaps a cow, some goats, and new clothes for all. It is the only way to make ends meet and pay the taxes.

Gulbi, Abdul Kareem's wife, has been ill of late. While chasing a neighbor's goat from the roof, where she had left drying turnips, she had sunk her foot through the worn earthen surface and broken the poplar branches beneath. Her leg was badly torn. The local herbalist—the awa—did his part while feasting on one of Kareem's chickens. Api suggested a poultice of hot barley meal, and Kareem engaged a brother akhoond who writes amulets of potencies that correspond to the price. His amulet was tied to Gulbi's leg for some days, then was lost. The leg finally healed. Gulbi, however, is not risking a relapse, so she sits pathetically spinning yarn.
A major match at Skardu featured four of Baltistan's seven rajas as players. The country's few horses are more for prestige and polo than for transport.
"A glance at the sun reminds Gulbi that zan must be ready soon. Calling over the roof to her neighbor, she asks for meh (fire). A little girl reaches through the thorns and hands her a few embers in a broken piece of earthenware. To this Gulbi adds bits of rotted wood for tinder and soon her hearth is ready. The large copper cauldron, half-filled with water, boils soon, and she throws into it several handfuls of roasted barley flour, stirring until the mix thickens. Hesitantly she takes a chunk of dirty white butter and melts it, carefully picking out the goat hairs. The family cannot afford melted butter every day. Gulbi does not have to call the family—they are suddenly there as she puts the steaming mass on a large metal plate on the floor. The family attacks the fat-rich food vigorously. Tomorrow the main meal will consist of zan accompanied only by a sauce of green herbs.

On the mountainside across the valley, since first light, younger villagers have been busy cutting and uprooting burtsé (wild artemisia). This dry-looking plant, invisible at a distance, is both the food of the ibex and the only free fuel the villagers can stockpile against the coming winter. Occasionally an apricot tree may be cut down or a small amount of cow dung dried, but burtsé is the main solution to the fuel problem.

"On the way home, one of the young burtsépong (gatherers of burtsé) sees an ibex and says he wishes he had a
A companion replies with a Balti proverb: 'The men who went out for burtse found ibex, the hunter found burtse.' Negotiating the ford is risky for the heavily laden men, but crossing by zak will cost money, and the winter bridges are not in place because the water level has yet to drop.

At one side of the hamlet, where two paths converge, there is what passes for a village square. The flat top of a very large rock, about nine inches above ground level, has two smooth holes in it that have served for generations as mortars. To one side of the stone two women are carefully cracking open apricot stones and collecting the kernels—the sweet hrtsu precious to the Balti because of their market value. Not long ago these 'sweet almonds' found their way to the hotels of India's larger cities. Cooks decorated cakes with them and ground them for a dozen different recipes. The Balti would bring them from every valley, in skin bags, to Skardu, where Sikh traders bought them. Now things have changed, and wheat flour brings the highest prices throughout the land. Other varieties of apricots—and there are many—also yield kernels, but these are pressed for oil.

'With little back-baskets (chorong) strapped over a sheepskin, and cloths over their heads, villagers carry night soil and pile it in various places in the fields. The night soil is of the utmost importance, since it is the principal fertilizer. The primitive latrines within and without the homes are kept reasonably inoffensive by adding earth and barley straw. Twice a year the latrines' stone walls are opened for removal of the contents to the fields. Only where the dried fertilizer is applied will anything grow.

"Kareem has not been lazing around since zan. He has been busy with the wall round his fields. The slope of the land demands that the fields be terraced. Material for the walls is abundant—rocks, stones, and fragments of all shapes. Kareem knows that unless his retaining wall is firm his whole field will collapse when the irrigation water is turned on.

"The Balti has few games other than polo. Sode, an eighteen-year-old, has a riding horse. For months he has used every spare moment training it to take its place eventually in a real game of polo. Even if he cannot obtain an invitation to join the official teams that play on the big polo ground, Sode will go to watch the game and enjoy the music and excitement. After the match is over he is usually permitted to attend the players' tea party, where buttressed tea is sipped while the merits and demerits of the other team's players are discussed.

Night comes, and dark mountains seem to fill the scene as a few villagers return from the mosque after the last prayer. The evening meal is ready. Although the menu rarely changes, there may be a treat tonight: homemade noodles or an egg. In spring there will be little to choose, but it is autumn now and the harvest is in. 'Eat, drink and be merry ...' is the Balti's autumnal philosophy.'
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NATURE IN

ROCK & MINERAL

By Paul Mason Tilden

In past installments of this column we have used the word “pegmatite,” without attempting any exact description of this most interesting lithologic phenomenon. We have indicated only that pegmatites—especially the granite pegmatites often called “giant granites”—provide mineral collectors with some of their happiest hunting grounds. For it is in these coarsely crystallized dikes and bean-shaped bodies, frequently found associated with large intrusive masses of granite, that the hobbyist looks for such treasures as aquamarine, golden and pink beryl; black and colored tourmalines; many of the complex and rare iron, manganese, and lithium phosphates; columbium, tantalum, thorium, and uranium compounds; and a host of other collectibles.

Geologists, too, find that the unraveling of the mineralogical sequence of events within a large pegmatite offers a stimulating investigative challenge and a field for speculation, since, over the course of the “lifetime” of a pegmatite, remarkable changes and replacements of both constituent and accessory minerals may take place.

Finally, it should be noted that the granite pegmatites are the source of several commercially important minerals—notably mica and feldspar—as well as several of the “newer” metals, like lithium and beryllium, which seem destined to play a key role in the successful harnessing of atomic power, as well as in man’s projected exploration of space.

It is worth mentioning that many collectors think of pegmatites, essentially very coarse-textured phases of some rock types, as occurring exclusively in the rock we call granite, which is basically a mixture of quartz, feldspar, and mica. This is a mistaken notion, since pegmatites may occur in other kinds of rocks as well—syenite and diorite are two examples. However, since the pegmatites in other rock types are neither as common nor as productive for the collector, they need only passing mention here.

Most of our knowledge about pegmatites and the mineralogical changes that may take place within them is based on inference, petrographic study, and a knowledge of the chemistry and behavior of minerals. No one has even witnessed the actual formation of a pegmatite, or the activities that may go on within one during its younger stages. Some of the minerals (such as crystaline quartz) that are found in such bodies have been created artificially in the laboratory. Yet the pegmatites themselves are formed within the crust of the earth under physical conditions that preclude human duplication. They are exposed to the attention of collectors and geologists only through the slow offices of erosion. In spite of this obscurity of birth and youth, however, geologists have a very well-formed notion of the processes that create pegmatites.

Over the course of geologic time, and doubtless continuing today, large masses of molten rock have locally eaten away and pried their ways upward from the depth of the earth into its outer crust. There is presently no general agreement among geologists and other earth scientists as to how such molten masses originate and commence to move. It may be by the local relief of pressure on deep-seated rocks, the added heat of supposed movements within the earth’s crust, the localized accumulation of radioactive heat, or by some other means.

In any case, upon the arrival of such a molten mass in the outer part of the earth’s crust, the process of cooling begins and the various mineral constituents of the mass start to crystallize each according to its solubility in the fluid. Minerals like magnetite, apatite, chromite, and other basic, which are least soluble, crystallize out first, leaving a watery concentration of silicate and alkaline matter that includes such volatile as boron, fluorine, chlorine, and small percentages of rare elements like beryllium, cesium, rubidium, columbium, lanthanum, yttrium, and others.
"Graphic granite," so named for strange markings that resemble hieroglyphics, has an oriented intergrowth of dark quartz that contrasts sharply with the white feldspar.

The whole fluid assemblage may be reed into cracks and fissures in the rock that surrounds the intrusion, and further crystallization takes place, eventually forming a pegmatite. Since the relative size of individual crystals depends, at least, on the rate at which the magmatic solution cools, mineral collectors expect to find the largest (though not necessarily the most perfect) crystals toward the centers of large pegmatites, in which the total amount of heat to be lost to the environment is greatest, and heat escape slowest.

Each of the pegmatic "liquor" as is squeezed into the narrow fissures—ranging in width from an inch or so up to a foot or two—loses its heat rapidly, and consequently the grain size of the unite formed is very small. Small "strings" or veinlets are commonly filled with a fine-grained, whitish mixture of quartz and feldspar called "siltite" by the mineralogists, but these:

CROSS SECTION OF AN IDEAL PEGMATITE

1. Wall Rock
2. Border Zone
3. Wall Zone
4. Intermediate Zone
5. Core Margin Zone
6. Core

STIPPLING indicates the relative density of some minerals (labeled at left) that are found in various sections of the onion-like interior-zoning of typical large pegmatite.
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Paul Mason Tilden, formerly an Editor of Nature Magazine, has been a rock and mineral collector himself, now continues his regular column in the pages of the combined magazines.

It is the big pegmatites, however—those ranging from several yards to several hundred feet in thickness, and up to a mile or more in length—that delight the collector and furnish museums with rare or exceptionally large crystals. Concentrated within these bodies, in coarse, pod-like units, may be aggregations of large crystal crystals of feldspar, quartz (sometimes of the amethystine variety), beryl, black tourmaline, mica, and perhaps a scattering of such rarer minerals as monazite, or uraninite and its brightly colored alteration products.

If a pegmatite exhibits a relatively rare alkaline-element phase, it may further afford the collector a number of the lithium-gadolinium rubidium minerals; iron and manganese phosphates; colorless or blue apatites; columbite; the tin ore cassiterite; red, green, blue, or colorless tourmalines; pink, white, or ash-colored beryls; and such of the several lithium silicates and phosphates, like spodumene and amylonite.

As examples of the great sizes that may be attained by the crystals of some big pegmatites, I once saw quarried blasts that were large enough to make “street” (as such concentrations are known to feldspar quarriers) in which many bushels of large feldspar crystals were loosely piled together like so many spilled bricks. In the same quarry, I saw a sheet of muscovite mica—actually a section of a larger crystal—that required two men to load aboard a truck! From pegmatites like this have come beryls weighing many thousands of pounds; feldspar; crystals weighing tons; spodumene crystals measuring thirty feet long. Is there any wonder that these bodies are called “giants’ granites?”

Many of the larger pegmatites, probably including a large percentage of economically important ones, exhibit: well-defined interior zoning of texture and mineral components. In some such bodies the onion-like zoning is so pronounced that the skilled amateur is able to locate his position within a quar
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led pegmatite, in respect to the plan of
the intrusion, merely by carefully ob-
erving the texture of the nearby rock
shells and the minerals they contain.

The part of the pegmatite that abuts
invaded host rock is often called the
border zone, and usually consists of sev-
eral inches of fine-grained quartz, feld-
spar, and mica, holding no particular-
izes for the collector. Next inward
on the border zone of an ideal pegma-
te (and ideal pegmatites are much
erlier to write about than to find in
these) is the wall zone, the first really
large-grained "shell" of the mass. In
rich individual crystals of feldspar and
quartz, the matrix begins to be promi-
ient. It is from the wall zones of large
igmatites that a considerable portion of
the valuable and strategically vital sheet
"punch" mica of the electrical and
electronics industries is secured. Abun-
dant black tourmaline, and perhaps an
occasional beryl crystal, may be found
in the wall zones of large pegmatites.

The next inner shell is called the
intermediate zone. This portion of the
pegmatite usually abounds in the queer
vegetation of quartz and feldspar
called "graphite granite," in allusion to
the occasional striking resemblance to
cone-shaped characters of ancient
heroes. If the black, iron-rich, and
economically worthless variety of mica
dotted biotite tends to be prominent in a
pegmatite, it will ordinarily be found in
large units in the intermediate
zone. Here, again, there may be a scat-
ered showing of beryl crystals.

The last two interior units of a zoned
pegmatite are called the core margin
and the core. In the core margin, there
may be commercial concentrations of
th muscovite mica and beryl. Quite
often the core of a large pegmatite con-
ists of a great host of milky, rose, or
oky quartz, with a large or small sprin-
ging of large and handsomely formed
feldspar crystals.

This core, in which the quartz is com-
monly of very high purity, is especially
attractive to collectors, particularly those
who make a hobby of cutting and polish-
ingsemiprecious gem stones. It is in and
situately adjacent to the core that the
best and most transparent aquamarine
kyles are found; perhaps it would be
more accurate to say, in the case of
low-working pegmatites, that tantalize-
fing fragments--of these brittle gem stones
are to be found, for the miners' dy-
namic, which uncovers the treasure, usu-
ally almost destroys it as well.

An interesting phenomenon some-
times associated with the core margins
is the large pegmatite is the so-called
"sea-urchin," a rounding, solid mass
of small wedge-shaped mica crystals tan-
ted together in the greatest disorder. At


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This has been selected for critical assay.

the huge and historic Ruggles pegmatite in Grafton County, New Hampshire, there occurred such a jumping producing some twelve feet thick and twenty feet long. While the A-shaped mica books found in such aggregations are worthless for any but the lower commercial mica grade (called “scrap”) in the trade, one might speculate, perhaps cautiously, that in such chaotic welters of mica lies the excess building staff of the pegmatites— the material for which Nature could find no orderly purpose.

It is interesting to observe that many of the sheets and books of mica that occur in pegmatites are crystal “palaces” in miniature. Between the infinite thin plates of mica crystals the mineral entrails may often discover crystals of beryl, garnet, magnesite, and other minerals, seemingly flattened almost in two dimensions. Some of these possess no crystal form of their own, but instead conform in outline to the structure of the mica. Of interest, too, are the crammed, broken, or distorted crystals found in many pegmatites, giving evidence of the immense stresses, strains, and pressures that obtain during the formative stages of pegmatites.

All told, there is much to be observed and much to be learned during some exploration in the “giant granites.” It is not difficult to determine the total yearly wealth, in tons and dollars, contributed to the nation’s economy by the pegmatites. Millions of tons of feldspar, millions of pounds of mica, and a modest amount of commercial beryl are won every year from the nation’s pegmatite mines and quarries; and these tons and pounds are easily translated into dollars.

Not so easily measured, however, is the annual return to the nation’s host of mineral collectors, whose rewards happily remain exempt from the ordinary ups and downs of the market place.

NOTICE

In next month’s issue, the Editors will offer the second in Natural History’s annual survey of children’s books in the field of science. Of 115 juveniles published in this year, some 59 titles have been selected for critical assay.

This list details the photographer, artist or source of illustrations, page numbers, and a brief review of the book. Before jumping to any conclusions, you may want to read all about it. Cover title, author, and publisher are given in italics.

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31—Stefan Martin
19—Charles Watcott
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Here 50 finished Questar bases are having legs fitted to them by Peter Dodd and James Reichert of our staff. They are choosing legs at random from a large supply, selecting one for the center, which will be adjustable by means of a telescoping smaller tube, and then choosing a pair, each one of which will fit both holes in the side of the base with just the proper feel. And feel is the right word to use, for we take leave of measurements at this point and work for the fit that feels just right.

We make a quantity of 1875 legs before we finish any holes in the base castings. The first step is to select drawn aluminum tubing at the Philadelphia warehouse of the metals supplier. We accept only those tubes whose diameters, including ovality, vary less than .003 inch. The lengths are then shipped to the Micromatic Company of Trenton, New Jersey.

Micromatic cuts them into short pieces and chamfers both ends inside and out. Then they centerless grind the entire outside surface to a tolerance of only plus or minus .0001 inch. One ten-thousandth inch. The group is then shipped to Pottstown, Pennsylvania, for a uniform, heavy anodizing, or sapphire plating, by the electrolytic method. This coating is actually quite thin, but very hard and durable for it is, being sapphire, of the corundum family. The 625 sets of legs, each alike in size to all the others within .0002 inch, are finally shipped to our factory at New Hope, where we make some parts completely and finish up others.

Meanwhile Micromatic has milled a long slot in 625 smaller tubes which slide inside the center tube and can be clamped at various degrees of extension. These smaller tubes do not need a close fit. A half-round block of milled aluminum alloy goes inside the slotted tube. One-half turn of a knurled knob will lock both tubes securely. Neither knob nor sliding tube can ever fall out to get lost.

Questar’s base casting is made by the Boose Aluminum Foundry of Reamstown, Pennsylvania. The alloy used is Alcoa No. 356 tempered to the T-6 condition. Because it contains 7% silicon it is exceptionally free-flowing in the molten state. It has the virtue of great resistance to the acids of perspiration or the corrosive salts of sea water, and retains its polish very well. We use the piece, therefore, without paint or surface treatment. If scratched or nicked, one may always polish out the defect and renew the surface luster. The workmen at Boose pour these castings one at a time into molds prepared from metal matchplates instead of wooden patterns.

After the tempered sand castings have been cleaned by sand-blasting, they go to Gerald Fegley’s shop in Pottstown, where he turns off almost one-half the metal in accurate machining. When turned to proper size on the engine lathe, Mr. Fegley himself puts them one by one in a large fixture which supports the piece and serves as guide while several holes are drilled, later to be tapped for fastening screws, and the three leg-holes are bored a trifle undersize, We have by this time sent several sample legs to Fegley and he has prepared a reamer and burnishing tool to ream each hole and burnish it to a mirror finish of exactly the desired size. When each piece is finished to his satisfaction, it is a handsome thing with no rough edge inside or out. Each is individually wrapped and shipped to us.

Then, as you see, the work of hand fitting each leg by selection begins. This job takes two men a day and a half to do 50 sets. The inherent ovality of tubing is what makes selection necessary within the .0002-inch range of tube diameters.

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2 Haida Bookends, reproduced from the lower portion of a slate totem, representing a bear. In the Northwest Coast Indian collection of the American Museum of Natural History. 8" high — $13.75 ppd.

3 Tibetan Bookends, reproduced from a sandalwood plaque of "The Magic Circle of the Five Protectoresses." From the Tibetan collection of the American Museum of Natural History. 6½" high — $19.50 ppd.

4 Dinosaurs: Their Discovery and Their World, by Edwin H. Colbert, Chairman and Curator of the Department of Vertebrate Paleontology of the American Museum of Natural History. 300 pages. Over 150 illustrations. This is a truly superb volume on the rise, decline and fall of dinosaurs. $7.85 ppd.

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Vol. LXX
DECEMBER 1961
No. 10

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NATURE AND THE MICROSCOPE

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COVER: This heron is a detail from one of the marvelously wrought late Gothic

tapestries called “The Hunt of the Unicorn,” now hanging in The Cloisters, New
York City. The popularity of this form of decoration derived from the almost
nomadic life led by the aristocracy as they moved from one castle to another.

Tapestries could be rolled up and moved, were less perishable than paintings,
and lent warmth and color to drafty stone buildings. By 1500, the approximate
date of these works, tapestries had begun to represent the natural world with
a great degree of accuracy. For more about birds in the hangings, turn to page 28.

The American Museum is open to the public without charge every day
during the year. Your support, through membership and contributions,
helps make this possible. The Museum is equally in need of such sup-
port for its work in the fields of research, education, and exhibition.
On occasion a mother or father will say to us, "Some day we must take the kids and 'do' the American Museum of Natural History." At such times, we realize that there are far too many persons who lack an understanding appreciation of the functions and scope of this venerable institution. It is impossible to "do" the museum in a day, a month, or perhaps a lifetime, for it assimilates learning and learning never stands still.

Those families that try to "do" the Museum in a day spend a lot of energy for the returns they get in terms of enjoyment and knowledge. They traipse from hall to hall, losing a minimum amount of time to each. At this rate, they look upon the habitat groups merely as pretty pictures rather than careful, factual delineations of animal and ant life. In their haste they lack time to read the labels side the groups. They keep moving at a pace that tires the feet and dulls the mind. They are proud to have seen much, not even realizing how little they have absorbed.

There are much more profitable and enjoyable ways of doing this. Our first suggestion is to slow down and take it easy. This Museum has been here almost a century and it will still be here a hundred years hence. Take in only a few halls at a visit. Read the labels, look at details, spend enough time here in each group to absorb its lesson. Sit down on one of those benches and gaze into a habitat group for a spell. You will find yourself wondering about the part of the world it represents, even imagining that you are there yourself. Devote special attention to such interpretative displays as the Warburg Memorial Hall, which treats of man's effect on his environment—the world of nature about him.

Those who take it slowly and keep coming back for more uncover new facets of the institution with each visit. They soon realize that, although habitat groups are often the main windows through which the results of scientific study and technical skill are seen, there are many other ways in which the citizen may use the Museum.

For adults who seek a fuller interpretation of the exhibition halls there are the gallery talks. These are free and informal. An instructor meets the group, takes them to a hall concerned, and discusses the subject at length. Subjects range from "The development and evolutionary max of the dinosaurs of the Cretaceous Period" to "The ancient civilizations of Mexico and Central America." At a modest cost, the Museum provides various series of lectures, which are given in the evening and cover a wide range of subjects. There are also lecture series for members.

In the Museum auditorium there are afternoon motion pictures (which are free), including films designed for older children and adults, or for persons of all ages. On Sunday mornings, over WNBC radio, Museum scientists tell of their own adventures in the search for knowledge. This radio program is called "Journey Into Nature."

Now that the space age has brought a growing interest in astronomy, The American Museum Hayden Planetarium staff is meeting the demand with additional lectures for all age groups. They even offer a course in astronomy for engineers, a technical presentation designed to give physicists and engineers engaged in aeronautics and space exploration an orientation in various aspects of astronomy.

There is also another course, of general interest these space-conscious days, called "Astronomy for the Family."

At dawn on a spring or autumn morning, bird watchers may be seen sallying forth from the Museum into Central Park. They are guided and instructed by Miss Farida Wiley, who has led bird walks in the park for years. It is astonishing how many species they find amid Manhattan's greenery. Twice a year Miss Wiley also leads groups behind the scenes in the Museum, taking them through the Exhibition Department and other sections to see how this citadel of science operates backstage.

There is almost always something going on in the Museum at night. Many local scientific societies hold their meetings in rooms provided for the purpose. Any interested person can drop by, sit in, and learn something. The meetings include those of the Aquarium Society, The New York Shell Club, The Linnean Society of New York, the Metropolitan Grotto of the National Speleological Society, The New York Microscopical Society, The Amateur Astronomers Association, The American Orchid Society, and many others.

These are only a few of the ways in which the Museum maintains close and lasting contacts with its friends and members. There are many who have been visiting regularly since childhood. To attempt to "do" the Museum in one day is as foolish as trying to eat, all at once, the food necessary for a week's nourishment. A number of meals, spread over a longer period of time, make for a happier life.
A Christmas survey of children's science books during 1961

A year ago, Natural History made its first annual survey of children's science books, a survey prepared by professional scientists associated with The American Museum. The Editors hoped that the reviews would help guide teachers, librarians, and gift-giving adults confronted with the task of choosing from a growing mass of material whose quality is uneven, to say the least. The response to that first survey was encouraging and indicated a need for continuing and, when called for, ruthless criticism by persons actively engaged in education and research.

This second annual survey discusses 44 of the 115 books received from publishers. Generally speaking, the reviews tend to be somewhat more favorable than they were last year, and I think that one reason for this may be a mild but heartening trend in publishing policy. More editors and writers are beginning to realize that books devoted chiefly to imparting facts rarely arouse a deep interest in science. Getting the facts straight and writing in an interesting style, while necessary, are by no means sufficient; these are simply basic, minimum requirements. The main task is delineation of the concept—the ideas and hypotheses that stimulate scientists to seek further knowledge. Concepts must make up the central element in any articulate and sophisticated account of science and scientific research.

Books heavy on facts and light on ideas have been all too common. We have had books that tell all about stars or dinosaurs and little or nothing about stellar or organic evolution—as if science were merely a matter of describing and measuring and classifying. There is no more effective way of stifling children's natural interest in natural phenomena. Rare fact, even bare fact embellished by skillful writing, tends to have a flat, "what of it" quality. Facts may be easier to present than ideas, but that is no excuse for avoiding the real challenge. The problem is to achieve an appropriate balance between information and ideas, and efforts to solve this problem are evident in an increasing number of children's science books.

Incidentally, this trend has already progressed much further in our schools. More stress on ideas is a major feature of courses developed during the past five years by the Physical Sciences Study Committee and by similar groups concerned with the teaching of mathematics, chemistry, and biology. Indeed, the steady improvement of all aspects of high school science teaching is sure to have greater and greater influence in raising the quality of children's books that may serve as supplementary reading.

It should be noted that the federal government, acting through the National Science Foundation, has played a leading role in this development. The Foundation is also supporting the invaluable work of the Science Library Program of the American Association for the Advancement of Science. Among the Program's publications are "The AAAS Science Book List" for high school students, a revised and enlarged edition of which will be published early in 1962; "The Science Book List for Children," which is intended for students up to and including the eighth grade; and "An Inexpensive Science Library," a list of selected paperback titles. One criterion for selection in such lists has been whether or not the authors present their information against a sound and adequate theoretical background.

The reviewers in Natural History's survey are well aware of another extremely important criterion. Their most frequent adverse criticism, this year, concerns the quality of illustrative material. Last year, I pointed out that many publishers regard illustrations as secondary problems, putting off discussions with artists until the last moment, when there is no more time for art work that is at once informative and original. As a consequence, illustrations may be too few or mediocre; attractive, but empty and misleading. Like some people, such art fails to live up to a good first impression. A typical experience is the beautifully drawn diagram, complete with color, which turns out to be utterly confusing when it is studied closely.

Failures of this sort raise a number of serious questions. They would not exist, or at least they would be far less common, if scientists had been consulted well before publication, and had taken the time needed to review thoroughly illustrations—as well as text—from the standpoint of the intended reader. In other words, the publication of substandard illustrative material almost always indicates that no technically qualified person has been intimately concerned with the all-important job of editing. One might have expected that, by now such quality control would have become routine, especially in science books and especially in books for children.

The disturbing thing, of course, is that the publishers involved are not living up to their responsibilities. One solution of the problem would be to employ trained science editors, specialists in the art of expressing technical ideas in straightforward terms. A few publishers have already taken this step. Another step is to draw on the experience of scientific consultants, although experience has shown that, by itself, setting up panels or boards of experts may not be enough. Consultants must be given ample time to consider manuscripts and illustrations, and to discuss details with writers and artists. Equally important, they must be well paid for their time.

In the long run, more attention will also have to be paid to the problem of who is to do the writing. Relatively few scientists have the time and qualifications to present technical information simply and vividly; relatively few professional science writers have the background required for preparing accurate and balanced reports on progress in complex areas of research. An approach that has produced good results is the use of both specialists—a collaboration between scientist and science writer. Plan to promote this approach are being considered by the recently formed Council for the Advancement of Science Writing an organization that includes scientists, publishers, and science writers.

Such developments suggest the scope of renewed efforts to improve children's science books. The search for imaginative; non-academic ways of describing research without technical jargon is just beginning to gather momentum as specialists in all fields become increasingly aware of defects in current methods of communication. The reviews appearing below represent an important aspect of this search. Progress can only be made by examining books to the critical examination of investigators, teachers, and others professionally concerned with imparting scientific information to nonscientists of all ages and backgrounds.
The reviews of current children's books in the field of science, presented on these pages, mark NATURAL HISTORY's second annual effort to provide guidance to gift-giving adults and more especially to librarians and teachers who are faced with the deluge of juvenile material, ostensibly presenting the sciences in factual fashion, which is poured onto the market each year. The 1961 score shows 115 such titles, of which 55 were deemed by the Editors to be worthy of scrutiny by its expert panel--five scientist-writers associated with THE AMERICAN MUSEUM. Of this 75, the panel rejected 31 out of hand. Presented here are reviews—by no means uniformly favorable—as the remaining 44. As in 1960, a general introduction has been provided by John Pfeiffer, himself an experienced science writer. The Editors hope that these annual assessments will serve as useful Diogenes' lanterns to all those seeking meaningful books.

**Astronomy**

YOUNGSTERS, excited by the thought of traveling in space, seek more and more information about space and astronomy. They must turn to books to satisfy this curiosity. Many of these books are good, but many are not. The mediocre and bad books may be products of haste, designed to tap today's ready market. Little can be done except to heed the cautions of reviewers. A worthy book deserves praise. Equally, if a book is unworthy, author, publisher, and public must simply consider that the...
of this volume—chemistry, physics, and astronomy—are treated separately, but many of the topics rightly belong to two or more fields. No sharp dividing lines are maintained, so the reader may discern the interrelations of science.

Most of the astronomy entries of concern to this reviewer were written by Patrick Moore, a well-known English amateur astronomer. He has rightly emphasized the amateur's importance to astronomy, and thus shows the amateur's view. As a result, however, his treatment is purely descriptive, with seldom any exposition of the scientific importance of a subject. Thus, when discussing double stars, he mentions their beauty and the difficulty of observing some of them, but without stating that visual and spectroscopic binary stars provide the astronomer's only fundamental method for deriving masses—an exceedingly important datum in the theory of stellar structure and evolution. This sort of omission may be based on the author's opinion that the young reader should be encouraged to do only what he is now able to do regarding this thought-filled subject. It is possible, on the other hand, that the reader may, in consequence, gain the impression that astronomy is concerned only with a superficial description of the universe and the things in it, and thereby miss the tremendous challenge of astronomical research.

A curious lack of teamwork between text and art in the astronomy sections may be the result of hurriness, carelessness, ignorance, or incompetence. Lack of time is the most likely explanation, but one or more of the other reasons is possible. Inquisitive young readers are certain to study this book in detail. If they find too many errors, no matter how small, their faith in the correct, but unexplained, statements could be severely shaken. Certainly, their derision will be generated by the moon's appearance above the North Pole of the earth in a diagram of the tides, as well as by the North Pole's emanation from Siberia on seven other diagrams. They may also be skeptical of the way in which binary stars appear to bounce off each other. A future printing may allow these and other lapses to be corrected. We may also hope that the editors of future volumes in the series will have the cooperation of professional scientists as well as volume and the series deserve the best from both fields.

Despite its catchpenny title, Space in Your Future, by Leo Schneider (Harcourt, Brace & World), is a really excellent review of astronomy—describing what is already in space. Mr. Schneider includes many simple experiments that will help young readers to understand some of the physical principles used by astronomers. The author stumbles into a few familiar traps—he includes cosmic rays in his discussion of the spectrum, and balances gravity with centrifugal "force." Since he does not make strong points of these items, the mistakes are relatively insignificant. It has been this reviewer's experience, on many occasions, to feel vicarious embarrassment on behalf of reputable astronomers whose help with a work of questionable value has been conspicuously acknowledged. The extent of their assistance—usually casual—is never really revealed. Whatever aid was given Mr. Schneider by the two renowned individuals he thanks, they have no cause for chagrin in this case. This is a good book.

Barbara and Myrick Land, the authors of The Quest of Isaac Newton (Garden City), have succeeded in presenting a little of the excitement of investigation and discovery in science by reviewing a few of the basic and far-reaching accomplishments of one of the best of scientists. As a footnote, it was part of the personality of Newton that he was slow to publish his works. In the case of gravitation and the moon, however, he had a different reason. The authors state that Newton knew that the earth's radius was 3,963 miles and that the moon was 238,857 miles away, and they imply that his calculations worked out exactly the same time. This was not the case. Newton first worked out the distance to the moon in terms of the earth's radius. By his theory, this ratio predicted a period of revolution for the moon that was observationally wrong. It was many years before better data on the earth's radius became available and his theory predicted the observations correctly.

The design of this book will not attract the older readers that its vocabulary seems to require. It is doubtful that a student in junior high will be captured by art that has visual appeal only for the third grader. But perhaps he will remember the old saw that one should not judge a book by its cover.

Copernicus, by Henry Thomas (Messner), is a pleasure to read. Although working in novel form, the author has invented conversations that are always to the point, and that advance the story significantly. Nicholas Copernicus and his friends emerge as real people with real problems. The hero's enthusiasms and frustrations are shared by the reader because they are placed in context. Mr. Thomas traces both Copernicus' education and the background of his early thoughts on the form of the solar system, and depicts the precarious times and the dangers Copernicus faced should he openly espouse his revolutionary ideas. The patience and caution of the pioneer astronomer in his later years and his troubles with his superiors in the Church are clearly shown. His masterpiece was finally produced as Copernicus lay dying, and Mr. Thomas outlines the slow but powerful impact it had on later astronomers—Tycho Brahe, Kepler, Galileo, Newton, and all to follow. One hopes Mr. Thomas will now give us as highly enjoyable biographies of Tycho and Kepler as he has of Copernicus.

KENNETH L. FRANKLIN

Geology and Paleontology

To part of science has more intrinsic interest and importance for the reader—young or old—than the story of man's evolution from his remote, simple beginnings. A century and a half of effort by paleontologists, geologists, and biologists has made known the main outlines of this story and provided the theoretical background for its understanding. Many books are published each year that attempt to bring this story to the younger reader. To many publishers and authors this goal must seem a simple one—pictures of bygone monsters are easy to reproduce, startling facts abound, and little effort is required to publish a colorful volume in the best "gee whiz" tradition. Books of this kind, attractive in appearance but scientifically as shallow as a puddle, are all too common: many thoughtful parents, librarians, teachers, and young persons must feel disenchantment when the textual content of such works is soberly assessed.

Method of locating earthquake's epicenter, diagrammed in Exploring Under the Earth.

Happily, Robert L. Lehrman, the author of The Long Road to Men (Basic Books), is well informed, writes with style, and has exercised unusual perception in choosing and organizing his subject matter. The result is a distinguished
in Britain are made of a peculiar limestone known as oolite, so named for the resemblance of its constituent grains to tiny eggs. True—and perhaps even interesting—but, in the context of this book, such a statement is more than useless: it merely distracts the reader.

A fault more serious than the inclusions of such bits of gratuitous information is Dr. Swinton’s failure to dwell on the vital processes of evolution revealed by the fossil record he is describing. For example, the transition from amphibian to reptile is dismissed in half a dozen sentences, while the dramatic and instructive aspects of the return of reptiles to the sea go altogether unremarked. The over-all effect of the book, alas, is little more than that of a colorful parade of amazing animals.

The Earth, by W. B. Harland (Franklin Watts), is intended as a general introduction to the story of the earth, including those rocks, minerals, and fossils that may be collected by the amateur naturalist. It is aimed at an audience 14 years old and older. Unfortunately, it is both poorly organized and poorly illustrated, and it incorporates most of the bad features of current college textbooks. The book opens with a brief history of geology that is difficult to grasp

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unless the reader already possesses advanced knowledge of geologic principles. The author then goes on to treat such complex topics as isotopy before the reader is given a chance to absorb more elementary principles. Many of the illustrations are difficult to understand and, frighteningly enough, appear to have been done without firsthand knowledge of rocks or landscapes.

Exploring Under the Earth, by Roy A. Gallant (Garden City), is an attractive book, aimed at readers of ages 10 to 14. Mr. Gallant presents the story of the earth with emphasis on the more recent findings of geophysics, particularly regarding the ocean's and the earth's interior. The author has shown keen insight in selecting topics that are of major scientific importance and are in the forefront of modern research. His list includes such matters as the earth's origin, its shape and size, features of the ocean floor, the origin of continents, island arcs and earthquakes, the origin of mountains, and many more. In fact, the book's chief drawback is that the author has attempted to cover too much in the space available. The result, in some parts, is a slapdash treatment of one topic after another. In six paragraphs, for example, the author covers the topography of the ocean floor, the composition of oceanic crust, continental drift, submarine canyons, and tectonics. Clearly, no adequate space has been allotted, as for earthquakes and volcanoes, the text is much sounder.

Mr. Gallant has not hesitated to present explanations for many phenomena that are no more than untested hypotheses. In each case, however, the source of the theory is given and the hypothetical nature of the explanation noted. The over-all effect of the book will surely be to stimulate the imagination and to make it clear that the many challenging problems remain for future scientists.

Mountains on the Move, by Marie H. Bloch (Coward-McCann), is an attempt to present the story of the earth briefly and simply to the 8- to 12-year-old reader, with emphasis on processes and events that can be witnessed on walks and trips. Several early chapters, covering basic processes of weathering and erosion, are well written and space among the photographs to convey their importance and reality to a young audience. Here, the photographs are well chosen and the text clear. For the most part, however, the book falls wide of the mark. There is a complete absence of diagrams, a fatal weakness in a book of this sort, for many concepts in geology are basically geometric and require diagrams for explanation. An attempt is made, for example, to describe the erosional history of the Rocky Mountains by words alone. Also, erroneous or misleading statements occur too frequently. Mark it: "failed."

Wonders of Rocks and Minerals, by R. M. Pearl (Dodd, Mead), purports to be a guide to the wonderful world of rocks and minerals. Unfortunately, it is poorly organized and startlingly incomplete. In the chapter on sedimentary rocks, for example, the commonest of all sediments—clay—is not even mentioned, but four paragraphs are allotted to that obscure, if spectacular rock, itacolinite. Equally puzzling is the lack of illustrations of rock and mineral specimens. Of the dozens of possible specimens, only five are illustrated at all: tourmaline, quartz, feldspar, diamond, and (of course) itacolinite. Another book, then, to be marked as "failed."

Ice Age Coming?, by L. G. Richards (John Day), devotes its main portion to an interesting, well-illustrated, informative, and up-to-date account of icebergs, glaciers, and icecaps. With this material the author obviously has firsthand experience, and the result is very good. It is unlikely that the book will be marred by a confusing and often inaccurate coverage of the geologic background and significance of glaciers. We are told, for example, that "... 50 million years ago ... huge cold-blooded reptiles from the depths of the sea ruled the land" and that, without glaciers, "... mountains would be only flat, dull hills."

On balance, a low "pass."

The Doubleday Pictorial Library of Nature: Earth, Plants, Animals is a companion volume to the Pictorial Library of Science, reviewed, above, by Dr. Franklin. The stated objectives of this second work in Doubleday's series are breathtaking in their scope: "... a description," says the publisher, "of the seas and crust of our planet Earth ... the story of how they came to be what they are ... a description of the planets and suns, and the story of how they evolved ... a description of the web of life, and the story of how man arose, to become part of it, finally to dominate it." Whew!

Perhaps the most striking feature of this unusual book is that its grand objective is in fact nearly achieved, so far as this reviewer's fields are concerned (comments on the work's competence in the realms of biology and ecology will be found on page 9 among Dr. McCormick's reviews). So far as geology and paleontology are concerned, the material is in general presented with clarity, literary style, and accuracy. The diagrams and photographs, many in color, are superb; without them it would have been impossible to compress so much in so small a space.

In spite of the enormous coverage of this book, the editors have managed to avoid oversimplification. Technical terms are used unashamedly and the reader is brought to grips with the essential details of many structures and processes.
This commendable virtue, however, restrains the audience to high school and older—rather than the younger-readers. A few weak points are almost inescapable in such a work. In part this is a reflection of the much shorter space given, for example, to astronomy and geology, when compared to the biological realm. For astronomy, of course, the reader may turn to Doubleday’s other volume. Even so, the opening paragraphs on the universe, for example, contain so many facts in such short space that a beginner’s comprehension will surely suffer.

In the geological sections—which are treated in this volume alone—the problem is even more serious. Unless one sentence in one caption for an illustration is read with care, for example, the reader will be misled into believing that features of old mountain ranges result from slow, simple wearing away of a primary jagged mass. The book gives an entirely erroneous impression of the distribution of gravity near continental margins, and the section on rocks is quite inadequate.

In spite of these shortcomings, this prodigious book, in the reviewer’s opinion, stands as the best single volume available for serious students seeking a comprehensive view of these fields.

In many parts of the world, at home as well as abroad and in humid lands as well as arid, conservation and management of water resources have become a major social, political, and economic problem. Although the scientific study of this problem must begin with an analysis of the geologic water cycle, for a full appreciation of the problem the student must treat ecological and political questions as well. R. H. F. for the Rod, by Elizabeth S. Helfman (Longmans, Green), is one of three books reviewed here that seeks to give the young reader an understanding of many sides of the water problem. This little book is a good, easily read volume that covers many aspects of water, including its chemical nature; the dependence of man on water; irrigation problems and techniques; problems of bringing water to cities; floods and droughts; and the industrial uses of water—as well as a summary of the TVA. Although the book needs more illustrations, the reader is unlikely to take water for granted again.

Water for People, by S. R. Riedman (Abelard-Schuman), is a small, ingeniously written and ingeniously conceived book on water and water problems for the 9-12 year old reader. The book’s most striking feature is the consistent use of inductive reasoning. The simple observations and experiments described will delight many youngsters and lead them to a firsthand understanding of physical principles and processes relating to water in all its manifestations.

**Botany and Ecology**

This year has seen a flood of gift-edge mediocrity issue from several large publishing houses. Relatively weak texts and undistinguished illustrations are combined, and then inflated by excellent design and lavish use of color to produce eye-appealing books that doublewill find their way into many American homes. Almost all begin with some claim of a success in a business sense, but for natural history education the gain is dubious. Perhaps it is better to have a mediocre nature book in the home than no nature book at all. But how much better it would be to have books of quality written (or, at least, critically appraised) by responsible authorities. Such standards are not difficult to attain but, to achieve them, publishers must recognize their obligation to the public.

As an example, The Golden Picture Book of Nature Walks by Clara Hussong (Golden Press), is supposed to be an introduction to the field natural history of eastern North America. The work is organized basically around the major habitat types—field, forest, and pond—but the sections on each of these habitats is subdivided along taxonomic, rather than ecological, lines. The result is a string of separate discussions of mammals, birds, reptiles and amphibians, insects, and plants. In addition, other sections describe a stream habitat, poisonous plants and animals, and the biological changes associated with the four seasons of the year. All in all, a commendable enterprise.

But let us consider the negative aspects of this book. Although there are many drawings, a number of the plants and animals mentioned in the text either are not illustrated or else are not adequately labeled in complex, multiple-subject illustrations. Thus, the reader’s familiarity with nature is presupposed. These illustrations, moreover, often are too simple; art, lack detail, and vary in accuracy from one page to the next.

The author, in turn, has fallen into the vulgar error of equating the word “animal” with “mammal.” She grates the ear with such strange combinations as “insects and animals,” and “animals and birds.” while mentioning mammals alone in sections on “field animals” and “animals that live near water.” The text is further marred by statements both teleo-
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"The Web of Life." Here we are told, erroneously, that a beech-maple forest is the climax forest in North America; "other parts of the Temperate Zone"; the Eurasian reindeer and American caribou are said to be the same species; a deciduous tree is said to grow only while in leaf; the star-nosed mole is called a typical dweller of the deciduous forest; box turtles are said to inhabit streams, and the skink is called a reptile (poorly). Among various other tidbits of unnatural history, all plants here are said to need soil and light and all bacteria make their own food by chemosynthesis.

In the book's discussion of desert life, one is given the impression that plants survive in these arid lands only by storing water in succulent tissues. Drought resisting and drought-escaping plants—which actually form the bulk of desert vegetation—are ignored. In discussions of habitats, such as deserts or grasslands, organisms from all parts of the world are listed in an indecipherable jumble that leaves one with the impression that they may all live side by side and enjoy catholic distribution.

From all this it is evident that the Pictorial Library of Nature fails short of perfection. Although many of its sections are clear and accurate, these are offset by others that contain gross inaccuracies and confused exposition. The young reader or adult layman cannot be expected to distinguish between technical accuracy and technical incomp-
Zoology

Children's zoological books are on their way to coming of age. This year, there are many fine choices for the young reader and, on the whole, the books are dignified and intelligently written. Gone are the adjectives (cute, quaint, adorable); gone are the anthropocentric descriptions. Instead, many authors prove that there can be great excitement in learning about living things simply because they are living, because of their habits, their ways of life, and their sometimes incredible means of adapting to their environments.

In addition to books on animal life, moreover, this year we find clearly written books on the "how to" of scientific experiments, as well as books on subjects that were formerly offered only to adults—about oceanography and marine biology, about such advanced biological principles as animal clocks and rhythms.

One disappointment is the illustrations in a number of these works. A child's book of zoology without illustrations is almost useless, yet many illustrations in this year's crop are so poor that they might better have been omitted. Sketchy, slovenly, many pay little or no regard to the details that often add the necessary dimension of beauty.

A glaring example is Meadows in the Sea, by Alida Mahlk (World Publishing Co.). This book could have been the younger set's version of Alistair Hardy's adult classic, The Open Sea. But the il-
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Illustrations are so soft and look so much
alike that the impact of the diversity and
the beauty of these myriad drifting ma-
rine plants and animals is lost. These
illustrations beg accuracy to the point
where one suspects they were rendered
by someone who never saw plant or ani-
mal plankton; they are pathetic. A fur-
ther paradox is that type and layout of
this book evidently were designed for
the younger child (third or fourth
grade), but the scientific terminology
and the levels of explanation are di-
rected toward a far more sophisticated
reader—one who knows the principles of
animal and plant classification. Too,
Mrs. Malkus assumes that the explana-
tions of activities are implicit in their
mere description, as when she recounts
patterns of plankton movement and dur-
nal migrations, but does not make clear
what kind of plankton she is writing
about.

Two of the four other books about the
sea are surveys of oceanography and
marine biology, with emphasis on the
techniques of exploration and some of
the discoveries. All About Undersea Ex-
ploration, by Ruth Brindze (Random
House), is a survey of some of the his-
torical and modern methods of oceanog-
raphy—techniques for depth and tem-
perature recordings, for geological
surveys, and for the study of currents
(including some up-to-date material on
the Swallow boats that measure deep
currents). Mrs. Brindze also describes
research vessels, Scuba diving, treasure-
hunting, drilling for underwater oil,
cable placement, and the like. It is a pity
she felt it necessary to cover all those
subjects. True, they are related to the
oceans (in that they take place at sea)
but should they be considered as part of
undersea "exploration"? I don’t think
so. The inclusion of so many subjects
is likely to leave the young reader at a
loss to decide where exploration ends and
exploitation begins.

The Challenge of the Sea, by Arthur
C. Clarke (Holt, Rinehart and Winston),
is more fun to read than Mrs. Brindze’s
book. Mr. Clarke, who has been writing
children’s books for many years, knows
his trade well. He elicits a sense of par-
ticipation in his reader and manages to
bring him to the brink of great new dis-
covers, which will occur only if the
reader himself makes a career of oce-
nographic research. This is exciting.
What better way to cultivate a child! Mr.
Clarke’s subject matter overlaps, to
some extent, Mrs. Brindze’s “Allabout”
treatment. He presents both historical
and up-to-date surveys of the techniques
of sea research. But he carries the story
further, delving into ingenious and dar-
ing developments in ship design, under-
water exploring craft, hydropods, and
fishery techniques. He takes his reader
into an imaginary future when men will
“become fish” and live under water for
long periods of time. There are science
fiction seascapes and illustrations of
some of the lesser known creatures of
the deep. Unfortunately, in some, the
artist has overlooked accuracy for sake
of drama, or even for no reason.

Searchers of the Sea, by Charles
Daugherty (Viking), is an exciting nar-
ратive tale about explore—not only the
mythical and real ones who sailed ships
across the oceans to find new routes to
fortune, but also the scientists who dis-
covered how the oceans moved, mea-
sured the tides, the currents, and the wind
patterns, and sent instruments to probe
and sample the ocean depths. Mr.
Daugherty points out how difficult it
was to understand things we take for
granted now—such as direction of
currents. He relates how long and ardu-
ous and searching this task was less than
two centuries ago. Ships were the only
means of crossing the ocean, yet no one
understood why it took two weeks longer
to go from London to New York than to
go from London to Rhode Island. A
study of this puzzle led to the discovery
of the Gulf Stream. Mr. Daugherty
writes about Banks, Nansen, Agassiz,
Manx, Iselin—the men who laid the
foundations of modern oceanography.
He writes about the famous oceanogra-
phic vessels, Endeavor and Challenger.
The people not only come alive in his
story; they are inspirational.

Under the Sea, by Maurice Burton
(Franklin Watts), is an encyclopedia of
the many species present in the oceans
from bottom to top. Described are the
algae, the plankton, the invertebrates
and vertebrates, the life of the shore, of
the shallow seas, and of the deep. Dr.
Burton does not shy away from scientific
names, mentioning them after he has
given the common names. As I read the
book, I wondered where it would fit in. I
think that it will be a good reference
for junior high school students. It will not
assist a collector, but it will help a stu-
dent who wishes to know a little more
about a particular fish or invertebrate.
It is well illustrated with line drawings
and very pretty watercolors—in which
many of the colors are close to reality.

The Quest of Louis Pasteur, by Pat-
F

From the student who would like to have readily available an almost limitless supply of ideas for experimentation, there are two excellent books this year, brimming with suggestions for experimental research and ranging in scope from the simple to the sophisticated. *101 Simple Experiments With Insects*, by H. Kalmus (Doubleday), is a superb reference book, filled with research ideas about almost every type of insect. This is handy because there are experiments that can be applied to the insect at hand, rather than experiments that require finding some remote, hard-to-locate species. The experiments are modern, simple, clearly stated, and most do not require elaborate equipment. Dr. Kalmus has called on the techniques of many outstanding research workers and has divided his book not into insect categories but into broad biological principles that can be demonstrated when using an insect as the experimental animal. These principles can be applied to many other species. The book presumes a good background in insect identification and knowledge of anatomy, which will limit its usefulness for younger children, but the high school student will find it a boon, indeed.

More Research Ideas for Young Scientists, by George Barr (Whittlesey House), is a more general work, dealing with chemistry, astronomy, electricity, weather, the human body, sound, light, water, and the like. The experiments are clearly outlined and supplemented by diagrams that are self-explanatory; in fact, these are so explicit that one might not even need to read the text to design the experiment. Some of the experiments are simple enough to be used in kindergarten—one of my preschool friends was amazed to find that her pen

ties shone after she placed them in lemon juice and salt—while others show the older student how to make an electric generator, how to test for color blindness, how to set up a working model of the solar system. There are ideas in this book to fill the needs of children from 6 to 16; there are ideas to fill science fairs for years to come.

If the two books, *Ducks, Geese, and Swans*, by Herbert Wong, and *Western Butterflies*, by Arthur Smith, are good samples of the works that Sunset Junior Books (Lane Book Co.) plans to produce, we have a significant new contributor to the field. Both are beautifully illustrated, clearly and well written, and filled with the kind of information a young naturalist wants—in the case of butterflies, where to find specimens, which specimens live in which ecological areas, and how to collect them. The illustrations are good enough to be used as a key to identification. Both books are concerned with the western representatives of these animals, but there is enough similarity to make them useful to children in the East. Considering the general beauty of the books, the attractiveness of the covers, the fine illustrations of the animals, and excellence of the prose, I feel that a child not yet a naturalist might well become one with such assistance. Certainly, the budding naturalist will be pleased with these additions to his collection.

Animal Clocks and Compasses, by Margaret O. Hyde (Whittlesey House), is a very different kind of natural history. It opens entirely new vistas for the child of 12 to 11. It will tell him new things about animals he may collect or observe, things he cannot learn merely from looking at and identifying the animal. Considered with the western dune fiddler crabs, but did not know that the greatest activity of the crab changes time each day—in rhythm with the tide—changes. The book contains excellent summaries of problems of fish, of bird, of insect, and of mammal migration. However, its

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Anthropology

A seeming collapse of good writing, combined with advances in inexpensive color reproduction, have led to a plethora of overillustrated volumes that one hesitates to dignify with the word "book." This general truism is particularly and painfully true of the juvenile fields that anthropology covers. Parents could do worse than to use one simple yardstick in selecting from among such books for their children's library—if the work in question is teeming with pictures and your child is over ten years of age, it is probably best to turn it down. no matter how reputable the publisher may be.

This and many other factors make it difficult to write reviews without gaining the reputation of being negative or even reactionary. Certainly one has to reject far more than one would like to. The following, then, is a selected list of recent publications, which for one reason or another—not all favorable—merit attention. The favorable side of the list should be far longer, but it will take an educational revolution and a good deal of consumer resistance to achieve that.

Most up-to-date material is on biological rhythms, on the attempts to understand how animal movements are biologically initiated. Mrs. Hyde has evidently talked with many scientists about their research. Her reporting is accurate, although she does not "hedge" sufficiently in some cases. For example, the theory that eels travel landward is not wholly confirmed as fact. Nonetheless, the author shows the serious student what a vast amount of work is still to be done, for we do not yet understand many of these relationships between organism and environment. This book will inspire observation and experimentation.

Treasures by the Millions, by Harry Edward Neal (Messner), is the sort of book one should read before visiting the Smithsonian Institution. Filled with tantalizing photographs, it relates the many adventures that took place long before that great museum's exhibits were created and the specimens placed on view. It tells how the Smithsonian acquired its name. (It seems strange that a place so clearly American was started by a grant from a British citizen, James Smithson, who never visited this country.) There are many stories about the histories of the exhibits, their problems, their successes. The research, the exploration, and the men who have made the Institution great are well treated throughout. This book will create a desire to visit our national museum, and the visitor who has first read this volume should particularly enjoy his trip.

Evelyn Shaw

Archaeologists and What They Do, by Robert J. Braidwood (Franklin Watts), is a first-rate account of the science, and of what it takes to be a professional archaeologist, by a leading professional of America's first archeological institution, the Oriental Institute of the University of Chicago. There is not a single picture in this volume, but the words, written in an informal, personal style, conjure images that teach and interest far more than most pictures can. In short, this is the best book on archeology for juvenile readers that has appeared in recent years.

Aside from an unfortunately silly title, The First Comers, by Alice Marriot (Longmans, Green), is an excellent introduction to the archeology of North America. It is an informal manual of archeological techniques, as illustrated by field work in America (with emphasis upon the Southwest). The reader gains a perspective both of life in prehistoric times and in interpreting the preserved remnants of that life, There is an excellent bibliography and an outline of the various states' Antiquities Laws.

Secrets of Minos, by Alan Houson (Whittlesey House), is a biographical account of Sir Arthur Evans—who discovered, excavated, and restored the almost forgotten city of Knossos, capital of the Cretan world. Mr. Honour has caught much of the spirit of this pioneer archeologist and Sir Arthur emerges with his dignity, character, and enthusiasm still intact—a miracle in these days of two-dimensional writing. This book certainly should catch the imagination of a boy or girl who has dreams beyond the mere economic.

Ships, Sails, and Amphoras, by Suzanne de Borhegyi (Holt, Rinehart and Winston), is an informative little book on the problems and the accomplishments of Scuba-equipped, underwater archeologists. There is a rich enthusiasm in the writing that ought to attract many to this special facet of the science.

A translation from the German edition, The World of the Pharaohs, by Hans Baumann (Pantheon), is a lovely, gentle book. It cannot be recommended too
highly. It is illustrated with first-rate line drawings and wonderful, full-page color photographs. The author tells of Egypt past and present, of the Pharaohs who created ancient Egypt’s splendors and the archeologists who recovered them after centuries. It is an Egypt seen through the eyes of the Egyptian archeologist’s son, Megili, whose eager inquisitiveness leads him along a fabulous trail that should make any American child worth his salt dream of the day when he, too, can explore the many wonders along the Nile.

The Indian and the Buffalo, by Robert Hofsinde (Morrow), is a straightforward account by a native Indian who has written dimly by books on Indian life. It is the study of how the bison was hunted by the Indian and how important these vast herds were, not only to Indian subsistence but to numerous cultural practices. Simply written, it is informative. But it is also a pathetic book: it does not (cannot?) recount the bitter story of the murderous slaughter of the herds by the white man and the real depth of that injury to the Indians.

A story filled with line magic is Throw Stone, The First American Boy, by Ted Sayles and Mary Stevens (Reilly & Lee). It transports the reader back to the time when the first people crossed the Bering Sea into the New World. It tells of their life as they drifted slowly south, seeking the game of the Ice Age. That remote world is seen primarily through the eyes of the boy, Throw Stone. The perilous events are dimmed by a mammoth that has the ring of authenticity. The authors have both authority and narrative power.

The American Indian, by Oliver La Farge (Golden Press), is a great disappointment. One opens this book by a distinguished writer, to find his fine views buried in a garish potpourri of exuberant illustration. One can almost reconstruct the scene where the publishers told Mr. La Farge that they wanted a children’s version of his excellent book on Indians “... loaded with pictures. Hit those kids right in the eye.” The undignified and certainly uninformative result is worthy neither of the author nor of the artists whose works are mashed into this rainbow heap. An apology, addressed to each Indian tribe and each Indian-respecting child in North America, should be included in every copy.

WALTER FAHRBRENS, JR.

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Aerial Aid to Archeology

Cameras, aloft, help to guide the spade

By DAVID LINTON

In the basement of the Turkish Army Geodetic Laboratory, Capt. Iham Durupinar was looking at photographs with the aid of a strange machine. Knobs and cranks projected from it, lights glowed in its interior. Captain Durupinar peered inside it through a pair of eyepieces hooded by blinders. It was a dull, routine sort of job—filling the gaps in the map of Turkey. For this purpose, the most inaccessible parts of the country had been photographed from the air, and it was the captain's job to measure distances and draw contours with the machine—a stereoplotter—and then transfer them to maps.

One of these inaccessible areas lies at the northeast corner of Turkey, in a pocket between Soviet Armenia and Iran. Here, rising 16,945 feet, is Mount Ararat where, claims biblical tradition, Noah's Ark ran aground after the great flood. As the captain studied picture after picture of the bleak, rocky terrain, he suddenly stopped and looked again: on a mountainside 7,000 feet above sea level and 200 miles from the nearest sea was an object shaped something like a ship. It was 500 feet long (close to the 300 cubits specified in Genesis) and its smooth, symmetrical outline formed a marked contrast to the surrounding slopes and ravines.

Now, this "find" has not yet been identified. A brief visit by a group, including American scientists, established that the steep-sided object has a grassy mound in its center. Small fragments of wood were found in the earth composing its rim. But any conclusions as to the origin of the ship-shaped mound will have to wait until a full-scale expedition is sent out to excavate it. In several respects, though, this episode typifies the new approaches to archeology that are made possible by developments in modern science.

The twentieth century has added a number of new weapons to the archeologists' traditional arsenal of picks, shovels, screens, trowels, and brushes. Perhaps the second most important of these new instruments is carbon-14 dating, the technique that earned its inventor, Willard F. Libby, the Nobel Prize. The other great twentieth-century contribution to archeology is likely to prove even more important than carbon-14 dating because of its range of applications. This is aerial photography. It figures not only in the chance discovery of possible archeological sites, as in the episode described above, but also in reconnaissance that can tell archeologists where not to look—not to mention its more obvious contribution in orienting and mapping known sites.

Archeology—if such it may be called—has no single inventor, but military reconnaissance and civil engineering are its godparents. Today, largely because of aerial photography, there is an enormous backlog of known or suspected archeological sites waiting to be investigated when funds and staff are available.

The discovery phase of aerial archeology relies on the fact that man has developed distinctive shapes (and in some cases distinctive sizes) for his constructions, which immediately set them apart from the works of nature. In dense jungle, for example, anything built by man will be rapidly...
observed as soon as men stop cutting back the jungle. But in the Yucatan forests, a straight line of elevated trees, visible only from the air, still traces Maya roads that might be invisible from a few yards away on the ground. The geometric arrangement of the lines marks them as human artifacts.

The same is true of burial mounds, house sites, or the earthworks of ancient forts. When very old, such features may be so obscured by later plant growth or cultivation that their shape cannot be perceived from the ground. Often they cannot be perceived from the air, either, except at those hours of the day when the angle of the sun throws their contours into relief. Such traces of early digging and building are called shadow marks.

Another, though much rarer, type of relief trace is revealed when a light snowfall is followed by wind that blows the snow from the more exposed parts of the landscape and piles it in the sheltered spots. Slight variations in elevation stand out in aerial photographs made at such times, and distinctive forms may emerge, indicating ancient human construction.

In places where the land is occasionally flooded, either by design or accident, a similar highlighting of fine relief may occur when a few inches of water cover the lower parts of terrain while higher parts are dry. All such relief traces are particularly helpful in locating the sites of ancient walls, ditches, and watercourses, as well as the slight mounds that usually mark the sites of ancient farms.

Until fairly recent times, man did not have organized methods for getting rid of the refuse he produced. In ancient towns the by-products of human existence, which we now consign to sewage and garbage disposal systems, were simply thrown into the street, whose level accordingly rose. When it reached such a point that rain water ran from the street into houses, the floor levels of the houses were raised, too. Thus ancient cities and towns tended to increase in elevation as their occupation continued. This rise in elevation is seen in pictures taken—under proper conditions—from the air. This is also why the shovel remains the basic tool of archaeology.

The most important traces left by man on the land, however, do not result from his moving the earth about but from his effect on its fertility. Such traces are called plant marks, and can be either positive (i.e., where man's disturbances have increased fertility) or negative (where they have decreased fertility).

Positive plant marks are formed where buried ditches, building sites, farmyards, stockades, garbage pits,
and similar remnants of human occupation make the earth above them more fertile than the surrounding land. When covered by crops, the sites may produce plants that grow taller and greener than their neighbors. The effects last for very long periods and the affected areas are likely to be sharply marked—so much so that they can be measured precisely on aerial photographs of a region. The ditches that surrounded Neolithic settlements on the Tavoliere Plain near Foggia, Italy, have long since been filled in but, in that dry region, the extra moisture they supply to the plants growing above them makes their pattern still visible from the air after 4,000 years. Over 170 Neolithic sites have been located in this one region, which measures only a little bit more than 1,500 square miles.

One of the most remarkable contributions made by aerial photography to archeology is in the discovery of the Etruscan city of Spina. It was built about 500 B.C. in the swampy delta of the river Po—not far from modern Venice. Spina is referred to in classical literature, but many archeologists disputed its site or actual existence until its ruins were discovered a few years ago through plant marks. Like Venice, Spina had canals for streets, and the whole pattern of the city was revealed by aerial photographs showing the positive effects of the ancient watercourses on the fertility of today's plantings.

Negative effects on fertility are also visible from the air: buried stone walls and streets may interfere with the root systems of plants growing over them, so that those plants do not grow as tall as others in the same field. The entire plan of the Roman town of Caistor in Norfolk, England, down to the sites of the forum, temples, and baths, was revealed through such negative plant marks in a RAF photograph taken in 1929.

Dry weather, particularly if it lasts throughout the growing season, generally favors the archeologist. In dry years, plants are forced to extend their roots farther downward to get water; in those years the encouraging or inhibiting effects of underground structures are most likely to be seen in the growth of plants on the surface.

In addition to these basic factors influencing plant marks, there are many variations that provide archeological clues to anyone trained to read aerial photographs. There are a few ancient sites, for instance, marked by plants of completely different species from those nearby. In southwestern Greenland, the Norse colonists, who came from Iceland in A.D. 985 and thereafter, introduced certain non-indigenous plants (whether intentionally or accidentally we do not know). Although the last of the colonists disappeared about A.D. 1500, the sites of their farms are clearly visible on that treeless terrain. The traces can be seen from the deck of a boat on a fjord, but aerial photography gives an even better over-all impression of the patterns on the landscape.

...
Centuries of history are revealed by aerial photograph, above, of Ashdown Forest, England. Between modern roads (1 and 2), a straight Roman road (3) marked by parallel ditches exactly 62 feet apart—was found. Hollow way (4), marks where none was visible in the natural ground cover. A rather rare effect was seen when Mill Heath, in Suffolk, England, was planted in 1947. The crop did not do well except in one spot, where a rich growth revealed the outlines of a Roman building. Apparently the lime in the mortar of the long-buried walls had neutralized the prevailing acidity of the soil.

Sometimes the soil itself reveals traces of ancient construction, even where there is no vegetation or where the ground cover has been plowed under. Ditches that penetrated the subsoil will show up in aerial photographs as lines of darker color because of their higher moisture content.

Roman road (center) survives as plant mark even where land is plowed over.
was the introduction of Spanish sheep-breeding methods after A.D. 1300.

Soil marks often reveal ancient systems of land division. The Romans applied their typically disciplined approach to the practice of surveying. Their fields were laid out on a grid plan very similar to the system of sections and townships that still stamps any air view of America’s prairie states. The basic Roman section was a square, 20 ares (2,330 feet) on a side. The sections were separated by roads, and every fifth road was a main highway, wider than the others. Sections were divided into smaller units, all rectangular, down to the jugerum, equal to about ¼ of an acre—the area that one man with two oxen could supposedly plow in a day.

The fields laid out according to this system—known as centurization—have survived in many parts of the Mediterranean world, for the Romans persisted in imposing this rather rigid plan on their colonies. Many of these fields can be identified from the ground, but it is only with aerial photography that the characteristic surveying plan is clearly grasped.

These Roman fields point up several principles of aerial archeology. Man’s patterns are revealed by soil marks in characteristic shapes and sizes; they have endured for centuries either because their traces remained in spite of later cultivation, or because they were incorporated into the latter-day landscape; and they often go unrecognized from the ground because they are too big to be seen at close range.

Large archeological sites may pass unnoticed for years because an observer on the ground cannot see their distinctive shapes. One of the most important finds in the United States in recent years is a large mound, some 70 feet high, at Poverty Point, Louisiana. The mound had long been known and had always been thought to be of natural origin. But in 1952 Dr. James A. Ford of The American Museum discovered from aerial photographs what had never been observed: the mound was surrounded by a series of earthworks including six concentric banks, the largest of which was almost a mile in diameter. Small quantities of stone implements had been found here years before, but the extent of the site had not been suspected. Subsequent excavation has established that the mound, like the earthworks surrounding it, was man-made, dating from about 400 B.C.

A particular class of archeological sites includes those now lying under water. Because of its reflecting surface, water is more transparent from over- head than from any other angle. The remains of submerged cities and sea-ports in shallow water can often be mapped with great accuracy from a single aerial photo. And from suitable pairs of overlapping photos it is possible to measure depths in the same

Rows of stones from ancient terracing, property divisions, and roads tend to show up as lighter lines. Even where old stone walls have been leveled and plowed under, the stones that comprised them have seldom been carted away. Surface erosion reveals the bands of extra-stony soil; the geometric pattern marks them as man-made.

Soil erosion patterns on a very large scale—discovered by chance—have even changed our understanding of Italian history. The poverty and infertility of southern Italy used to be attributed to Roman or early medieval farming methods. Examination of photographs taken during World War II, however, showed that the cause

**Characteristic rigid field plan marks Tunisian town as former Roman colony.**
England. Dark lines are due to subsoil's having been turned over originally for ditches; light lines are the old ridges.

way that the elevation of land is determined in topographic map-making.

The present state of the art limits aerial photography of underwater sites to depths of about 60 feet, even with optimum visibility. (The sun should strike the surface at an angle of slightly under 45° to minimize reflection.) But archeology is bound to profit from the research in underwater mapping now being carried on by the U.S. Coast and Geodetic Survey, and refined techniques will certainly be introduced. Even now, the camera can see considerably more than the eye because the former's sensitivity can be controlled. Film and filter combinations can be chosen for maximum sensitivity to those wave lengths of light that penetrate water best. Contrast can be controlled by choice of film and development. A research unit of the British Army found that details in shallow water (less than 20 feet) were recorded best with a red filter, while those in 20 to 50 feet of water were best seen on a panchromatic film exposed through a green filter. But there has been little study of special photographic techniques for archeological use.

Some submerged remains, however, have already been revealed by aerial archeology. The most luxurious of seaside resorts for ancient Romans was Baiae, near modern Naples. Today it is under 30 feet of water, but its streets, buildings, and open squares are recorded on film. It would take months for divers to come up with an equal amount of information, and it is unlikely that they could ever make as accurate a map, since terrestrial surveying techniques are hard to use under water and depths are too small for oceanographic apparatus.

With the aid of aerial photography, the archeologist may find valuable clues even where there is no sign of human handiwork. In territory where cave dwellers lived, pictures can reveal the mountains in which caves are most apt to be located. Where shore lines have changed, photography can locate ancient beaches on which coastal peoples must have lived, and where their campsites and shell middens are likely to be found ("First Traces of Man in the Arctic," Natural History, November, 1960).

In arid lands, certain surface features may point to sites of ancient springs, now dry. Springs have always been the focus of desert life, and they are the first places to look for remains. Aerial reconnaissance is particularly important over desert and other barren land because it can tell us where not to look, by eliminating the areas that were unsuitable for habitation.

It is in the study of surface features of the land that archeology has been able to repay a small part of its debt to geology. Geology has traditionally provided the framework for dating archeological sites; but recently it has been possible to date river courses, beaches, and other surface features by mapping the archeological sites on them and dating the sites by the carbon-14 or other methods.

After a site is discovered—either from the air or on the ground—a field investigation is necessary to establish its history. Here, too, aerial photography can be extremely useful. It can
eluclalitate the history of the surrounding terrain, showing where rivers have changed courses, where lakes have dried up or dry land has been flooded, or how erosion and landsides have changed the shape of the land. It can determine the geographical orientation of streets and buildings—a point of considerable interest, because some ancient peoples built their temples to face certain points in the heavens and this knowledge helps us to reconstruct their system of astronomy. Aerial photography can also give us precise measurements of the site itself, including the width of streets, thickness of walls, and gauge of cart tracks, as well as various indexes from which it is possible to estimate the population of a long-dead town.

The techniques by which aerial photographs are made to yield such detailed information have been refined over the years. Consider the matter of determining distances. Most of the aerial photographs made today will yield precise measurements of vertical as well as horizontal dimensions. These measurements are made in the same way that the human mind "sees" in three dimensions: by comparing two (or more) pictures of the same thing taken from different viewpoints. A human observer depends on two "pictures" recorded by eyes only 2½ inches apart. If the human looks at a landscape 2,000 feet below, the difference between the image seen by one eye and that seen by the other is insignificant. Photographs, however, are taken at intervals of hundreds of feet and the relief on them, when paired, is proportionally greater. Although any pair of pictures can be used, some will yield more information than others. To appreciate this, it is necessary to understand the basic types of aerial photographs, classed as either "oblique" or "vertical."

Oblique photographs are those taken at an angle—not straight down. They are often very useful in the discovery phase of archeological research because they show some kinds of details that do not show up as well on vertical photos. But there is an infinite number of possible viewpoints for obliques of a site and only one may be useful. Furthermore, that one may be useful only at a certain season or time of day. While it is possible to take horizontal and vertical measurements from pairs of oblique photos the process is difficult. Oblique photos, therefore, are most useful for reconnaissance or for recording sites that have already been discovered.

Vertical photographs are taken straight down (or as close to straight down as flying conditions permit). Correction can be made later for tilt of the plane, wind drift, and variations in altitude. The vertical photograph is like a map—in fact, most modern maps are based on verticals—and is extremely useful for making precise measurements. Most verticals are now made by automatic equipment that takes the pictures at fixed intervals as the plane flies along a predetermined course. Since these pictures overlap, there are always at least two views of every point on the ground.

The pairs of pictures are useful for reconnaissance as well as for measurement, because the vertical relief seen when they are studied is considerably exaggerated. Overlapping verticals—or stereo pairs—are used for making topographical maps, for prospecting, for planning construction projects.
Mosaic of overlapping aerial photographs shows ancient site near 'Uqayr, at edge of Jafurah sands along Persian Gulf. The ancient pattern of the fields and irrigation ditches is slowly being covered by desert sands. Although first spotted from the ground in the 1940’s, the site was again brought to the notice of archeologists by aerial photography on behalf of a geological survey for oil. Photographers of Aero Service Corporation flew over the site three times, taking three sets of overlapping photos; later the firm made these prints into this mosaic. The section outlined at right is shown in enlargement on following page.

and even for assessing taxes. The majority of aerial photographs now available are of this type.

The main problem of vertical photography, and the factor setting the limits of its accuracy, is ground control. Ground control involves relating the photograph to known points on the ground, and it is through ground control that the photogrammetrist finds out what corrections are needed for the tilt of the plane, wind drift, and variations in altitude and speed. Ground control is not so much of a problem in places that have been extensively surveyed and where there are established bench marks—geographical reference points marked on the ground—whose exact positions have been determined. Even so, considerable groundwork by surveying parties may be necessary to relate bench marks to points that can be identified in photographs.

In unsurveyed territory, and especially where there are few permanent landmarks, ground control can be much more of a problem than the photography it is intended to control. Prospecting and mapping companies have had to send teams through jungle and desert, and to land them by helicopter on mountain tops to establish
ground control for aerial surveys. In recent years, electronic devices have dramatically reduced the number of ground control points that must be established. SHORAN, for example, is the abbreviation for a short-range radio navigation system, part of which is carried aboard an airplane and the rest contained in small, automatic ground stations that can be moved from one location to another. The posi-
tion of the plane in relation to several SHORAN stations on the ground can be automatically determined and recorded at the instant a photograph is taken. The entire Canadian Arctic was mapped using this control from 1952 to 1958, although the only previous survey in many places had been made with dog sled and sketch pad.

The photogrammetrist's dream is a ground control system that would require no ground stations at all. The closest approach to this now operating is Doppler radar. With this system, radar signals are sent out from the plane in four directions and "bounced" back by the ground. The difference in frequency between the signals sent and the echoes received reveals whether the plane is moving toward the point of echo or away from it, and at what speed. The time it takes for the echo to come back reveals the distance from the plane to the echo point. The computations required to make instantaneous use of all these data are made by a small computer. A certain number of known ground control points is still required with this method, but the number is greatly reduced.

Very little aerial photography is carried out originally for archeological purposes. (The current survey of the area to be inundated by the Aswan Dam is a rare exception.) Usually the archeologist uses photographs taken for some different purpose--mineral-prospecting, map-making, or road-building are typical examples. One of the great advantages of working with aerial photographs is the sheer number available. Over half of the earth's land area has been photographed at least once, and some countries (England and Canada, for example) have been systematically photographed in their entirety. Oil companies, highway and waterway authorities, flood control and soil conservation agencies, and even lumber and power companies have extensive files of aerial photographs generally available to the archeologist. These supplement the files of government mapping and geological agencies. The Poverty Point find is a good example: it resulted from a study of the survey photographs of the Mississippi River Commission.

Not all existing air photos are helpful, of course. Many are on too small a scale, taken at the wrong time of year for plant marks, the wrong time of day for shadow marks, or taken by methods less helpful for archeology than for their original purpose. But since no archeologist has ever looked at most of these photographs, they should not be dismissed lightly.

No practicable amount of study on the ground can encompass the sheer size and quantity of information that aerial photographs can record. A single picture can give a comprehensive view of an ancient community--its forms of agriculture, land division, structures, tombs, canals, roads, fortifications--and its relationship to other communities. In short, aerial archeology brings us as close as we are likely to come to seeing the way of life of an ancient people as a functioning entity.

Ship-shaped form in the rugged terrain near Mt. Ararat, right, was discovered accidentally when Turkish Army map makers were working over air photos.
Rising from a clump of yellow iris at left is a woodcock, and a mallard also flies from stream edge. At right can be seen the tail of some diving duck.
OF BIRDS AND A LEGEND

TRUTH AND MYTH ARE WOVEN IN TAPESTRIES

In the fourteenth and fifteenth centuries, an ancient art became a highly organized industry. During that period, under the patronage of kings and dukes of France and Flanders, tapestry making reached a peak of perfection never before dreamed of. Works of hitherto unimagined magnificence were loomed to decorate and warm the drafty castles of the aristocracy, to beautify churches, and to lend distinction to the homes of wealthy tradesmen. The most important centers of the art were ateliers in Paris, Arras, and Tournai.

Tapestry making is one of man's most ancient crafts, and its very origin has been lost on the threshold of the historic era. Basically, the technique is a simple one. The

Small frog, nearly invisible among the welter of flowers in the seventh tapestry, is the only amphibian in the hangings.
warp threads, which lie parallel to each other, are held taut in the looms. Weft threads, which form the pattern, are woven in and out of the warps, and are then beaten down so that they completely cover the warps. The latter then appear only as ribs in the finished textile. In the early tapestries, the principal material was wool, but silk and metal threads often enriched the design.

Traditionally, it has been said that weave in tapestries is a more significant criterion of its worth than is the design—that no matter what the pattern, it is the workmanship that identifies it as of greater or lesser artistic value. To this theory, however, the tapestries of the Middle Ages give the lie, for the brilliant designs are themselves typical of this zenith of an art form. Here both qualities are combined with an accurate mirroring of the people of the time and the world in which they moved in a manner that perhaps has never been equaled in any other medium. Of all such medieval artistry, perhaps the most magnificent are the so-called unicorn tapestries now in The Cloisters, Fort Tryon Park, New York City.

The unicorn tapestries may have been made at Tournai, a Flemish city that was nearly as well known as Arras, whose name is still synonymous with the art. Early Gothic tapestry patterns had leaned heavily on outline drawings to achieve their effects. With the late Gothic came an increased awareness of the natural world, and thus an increased realism that was reflected in the treatment of tapestry subject matter. The woven flowers, for the most part, were those that really grew somewhere in Flanders or France. People’s faces were often portraits of patrons. Dwelling places were shown in three dimensions. Animals were usually representations of living beasts.

The unicorn group includes six full tapestries, each one of which covers about 150 square feet, and a small fragment of a sev-
enth. Their history is still somewhat obscure. It seems certain, however, that five of them were made for Anne of Brittany on the occasion of her marriage to Louis XII of France on January 8, 1499. The other two in the series have been dated about fifteen years later, when Anne’s daughter was married to Francis I. Actually, they may have been made contemporaneously in different workshops. Francis was the godson of François de la Rochefoucauld, in whose family home at Vertueil, in southwest France, the tapestries hung for many years. They suffered innumerable vicissitudes, and changed hands at least once—there is even a story that, during the French Revolution, they were used to keep potatoes from freezing. Eventually, they were reacquired by a Rochefoucauld, and hung at Vertueil until John D. Rockefeller, Jr. purchased them in the early 1920’s. In 1937 he presented them to The Cloisters, where they have hung ever since.

The tapestries tell of the hunting of the unicorn, a beast so virtuous and beautiful that, according to one belief, only a single animal inhabited the earth at one time. The unicorn legend dates from pre-Christian times, when such one-horned animals were thought to possess unlimited power. Gradually this belief worked its way into Christian myth. From the third century A.D. to the Reformation, the animal was a symbol of Christ. In the Middle Ages it was believed that a unicorn could be caught only by a virgin. If she approached the fleet, ferocious animal, it became suddenly tame, put its head in her lap, and was easily caught by a huntsman. In Christian allegory, the virgin was Mary, and so Christ renounced the characteristics of God in the interest of mankind. During the age of chivalry, the story of the hunt was used to dramatize courtly love.

Interestingly, the unicorn is the only fabulous beast that managed to leap the gulf between the ancient bestiaries and the modern
These pheasants, surrounded by cherries and flowering hawthorn, exemplify the rich details of these tapestries. Notice reflection of the bird in the water.

mind. Griffins, dragons, and their like were left behind in the mists of legend, but the unicorn persisted, perhaps aided in its survival by the religious stature given it during the age of faith. Even during the Renaissance, with its revival of the scientific spirit, a "unicorn horn"—actually a narwhal tusk marketed by canny Scandinavian seamen, could, according to one authority, "buy a city" for its ability to detect poison. As late as the seventeenth century the French imposed a duty of fifty sous per pound on unicorn horns brought into the country.

In the unicorn tapestries, myth and almost photographic realism are interwoven. Scholars have explored this realism, and have identified the royal figures, the hunting dogs, and even 85 per cent of the 101 different kinds of plants represented. Oddly, however, one facet of the tapestries
The sixth tapestry's vivid colors and three-dimensional treatment are particularly striking. Six tame doves are near cote and two swans adorn castle pond.
A woodcock and a mallard on stream in fourth tapestry are surrounded by broad-leaved pinks, at left, corn marigolds, center, and English bluebells, right.
Late Gothic tapestry techniques differed sharply from their predecessors in using shadings that gave life to even the most intricate and delicate of subjects.
The partridge was often used to represent evil, so birds' appearance in this tapestry probably rested on their familiarity rather than on symbolism.
A domestic white duck, its wings outstretched to show that it has just settled on the water, swims near a shore on which are field daisies and a yellow flag.

has been largely overlooked. On leaves, in streams, in a pool, on treetops, and on a fountain edge are birds: all told, thirty birds (and two disembodied tails) of about thirteen different species. Most of them can be identified. But why were these particular birds chosen? The unicorn is symbolic. Do the birds have mystical significance, too? Perhaps this question can best be answered, at least speculatively, by considering the hangings and their contents one by one.

The first and last tapestries, entitled "The Start of the Hunt" and "The Unicorn in Captivity," are the two that may have been done about 1515 for Francis I. Neither of these includes birds in its highly stylized design. The five earlier tapestries are infinitely more realistic. Flowers of the marsh are shown in marshy places, perching birds are found in trees, and aquatic birds in the
Some scholars believe that the squirrel had special significance for Anne of Brittany, as it also appeared with her in an earlier tapestry and a painting.

water. Of these five hangings, “The Unicorn at the Fountain”—the second in the series and the first made for Anne of Brittany’s marriage—is perhaps the best known. In the center stands an elaborate fountain (pp. 40-41), below which, dipping its horn in stream water, in its classic duty of absorbing poison, kneels the unicorn. On the rim of the fountain are four birds. Two are pheasants, and opposite them are two European goldfinches, one a young bird whose black adult markings have not developed. In the foliage to the left of the fountain are another goldfinch and a bird that is either a willow warbler, a nightingale, or an imaginary cross between the two. This bird’s yellowish breast suggests the warbler, but its rusty tail indicates that it is a nightingale. In the stream can be seen the tail of one duck disappearing into foliage, another duck (perhaps a cross between a mallard and a domestic breed), and a woodcock. It is perfectly possible to lean on allegory to explain why most of these birds are in the tapestry. Birds have represented the souls of men and dozens of other religious-mythological aspects of man’s beliefs from the times of Paleolithic scratchings on rock. Pheasants have been considered “thunder-birds.” The goldfinch, which is fond of eating thistles and thorns, became an accepted Christian symbol of the Crucifixion because of the relation of all thorny plants to the Passion. The nightingale, believed propitious to weddings (and this tapestry was made for the union of Anne and Louis), also was a symbol of devotion, while ducks were augurs of the weather. The woodcock, alone, apparently has no symbolism attached to it in any culture. Thus it seems odd that, if allegory had been the avowed intention of the tapestry designers, this bird should have been included at all. The anti-allegory point of view can be made stronger
by an inspection of the succeeding tapestry, “The Unicorn Tries to Escape.” The first bird we notice is one flying from the very top of a tree at the hanging’s upper left. The bird is probably another goldfinch, although repair in this area has been so extensive that it is hard to be certain. In the stream that runs along the bottom of the tapestry are several other birds. One of these in some ways defies identification (see page 31, top). It most closely resembles a little bittern, whose breast feathers are rusty colored in nesting season. In the center, a pair of partridges peer out between clumps of clary and field daisies (see page 36). Again, if symbolism were the artists’ intent, the partridge would hardly have a place here. In legend, these birds are lascivious, cunning, depraved. It seems more logical to believe that the partridges were introduced because they were common game birds. Completing the stream-edge picture are a mallard and a domestic white duck, representations of fowl that certainly were very familiar to the Flemish artisans.

The Unicorn Defends Himself” is the fourth tapestry. Here another goldfinch flies from an upper tree limb, while two woodcocks and two mallards busy themselves in or near the stream. But in this striking work is another bird. In the lower right is an imposing figure—very similar to our great blue heron (see the cover). Now, if one is to seek symbolism, here it is. The purple heron is indigenous to Flanders, and it has been suggested that the legendary phoenix is really the purple heron (as phoeniceus means “purple”). Unfortunately for symbolists, the tapestry bird much more closely resembles the gray heron, a common frequenter of Flemish marshes and streams, than it does the purple heron.

The sixth tapestry (the fifth is only a fragment depicting a portion of the maiden, a hunter, and the unicorn) displays “The Unicorn Brought to the Castle.” In this work, the royal couple in the center are probably Anne and Louis. Here, again, two goldfinches are to be found. Allegorically, the pair could represent the Resurrection,
The staff of Natural History wishes to thank Margaret B. Freeman, Curator of The Cloisters, a branch of the Metropolitan Museum of Art, for her generous cooperation, which made this article possible. Photographs were taken by Lee Boltin.

a theme in many contemporary works, or they could be augurs of disease. Historically, in contrast, these small birds were familiar to Flemish town and country dwellers alike, and were often kept as pets by children, who tethered them on strings.

In the center of this tapestry are two swans and a flock of doves (see page 33). Certainly swans meant good luck, while doves represented congregations doing good work. But, allegory aside, both birds were ordinary adjuncts to the aristocratic households of the late Gothic period.

We must conclude that while tapestry artists may have used symbolic material, they gathered it by observing the exciting natural world around them that revealed its realistic beauties.

Today, these seven tapestries march in an eye-filling procession round the gallery assigned to them at The Cloisters. In all but one of the great hangings, in the company of real royalty, realistic huntsmen, or identifiable birds, flowers, and dogs, strides or fights the genuine allegory—the great white animal whose horn is a sure cure for all passion, for epilepsy, worms, and plague.

From pre-Christian days to the twentieth century, the unicorn—an animal composed in equal parts of rhinoceros, antelope, goat, and faith—has been captured eternally. Immortalized in bronze, oils, ivory, and marble, the mystic beast is nowhere more magnificently enshrined than in the tapestries that bear its name, caught in the threads of its own mythos and serenely unaware that it is an anachronism in an intellectual climate in which truth, not legend, was considered to be the ultimate in beauty.

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Modern astronomy and its proofs of the theory of relativity

As in all sciences based on the interpretation of observed data, a recurrent problem in astronomy is that increasingly precise observations eventually reveal minute phenomena, which can no longer be explained by existing theories. In some cases, it is sufficient to introduce slight modifications into current hypotheses; but at times an adequate explanation demands the adoption of an entirely new system of assumptions and physical concepts.

At the beginning of the twentieth century, it was a well-known fact in celestial mechanics that the motion of Mercury in its orbit could not be accounted for exactly by Newton’s theory. Mercury’s perihelion (the point in its orbit nearest the sun) is expected to creep gradually in the plane of the orbit under the combined attraction of the sun and planets. In other words, the entire orbit is slowly rotating in space (see diagram, above). But it is creeping faster than Newton’s theory predicts. The additional displacement amounts only to about 43 seconds of arc, or less than 1/30,000 of a circumference, per century. Yet this small quantity is readily observed and was a cause of nagging concern to nineteenth-century astronomers. Several phenomena in the domain of physics, such as the behavior of light in certain experiments, were equally puzzling and at variance with current theories.

Radically new ideas concerning the velocity of light and the concept of time were propounded by Albert Einstein in 1905, in his Special Theory of Relativity. A few years later, in 1916, his General Theory of Relativity directed itself more specifically to a new interpretation of the motion of matter in the universe. The word “matter” is
Deflection of light by massive bodies, diagrammed above in exaggerated fashion, was a further Einstein prediction.

used here advisedly: not only did the new theory pertain to the motion of familiar celestial bodies, but it dealt also with the motion of light rays themselves, insofar as they behave like streams of material particles.

From the mathematical equations of Einstein's 1916 theory, it was possible to predict three astronomical phenomena capable of being verified by observation. All three have been found to exist. Although their effects are very small, and therefore difficult to measure accurately, the numerical results of the measurements are in good agreement with the predicted values of Einstein's theory.

One cannot, in these few pages, present the reasoning that led Einstein and his followers to their startling conclusions. The peculiar vocabulary of relativity does not lend itself to short definitions. Although the three predicted astronomical phenomena receive a rigorous formulation in Einstein's theory, the reader is cautioned to remember that they are described here in analogies of more elementary notions. The end result is the same, but the justification is necessarily approximate.

The first of these phenomena is the already familiar advance of the perihelion of Mercury. Its cause may be inferred from an analogy. We are taught that the shortest distance between two points is a straight line; yet if a ship sails from New York to Cherbourg, it is obvious that it cannot travel in a straight line because it must follow the earth's curvature. For the shortest trip, it must travel along a geodesic line (better known as a "great circle route"). Relativity assumes that the presence of a massive body, the sun in this case, creates what may be termed a curvature of the surrounding space. Admittedly, there is nothing tangible to this curvature, but it is used as a convenient mathematical representation. As with a ship sailing the ocean, a planet travels around the sun along a geodesic of the curved space. When the equations of such a motion are developed, it is found that the planet will return to perihelion after each revolution precisely in the manner revealed by observation. This excess motion of the perihelion decreases as the distance from the sun increases. Thus it is greatest for Mercury, but is still appreciable for Venus and the earth, and has been observed for all three.

The second phenomenon is usually called the Einstein shift or gravitational red shift (see diagram, right). The color of light and the pitch of sound, both of which travel in a wave pattern, are determined by the frequency of the wave (the number of wiggles per second, if you wish); high frequencies correspond to the blue end of the color spectrum (rainbow) and, in air waves, to high-pitched sounds, whereas low frequencies are characteristic of the red end of the spectrum (and of airborne, low-pitched sounds). If a sound emitter is approaching the observer, the wave pattern is compressed between the observer and emitter, the frequency is higher, and so is the pitch of the sound. Conversely, if the emitter is receding from the observer, the wave pattern is stretched out between the two, and the pitch is lower. A familiar example of this effect is the sudden drop in the pitch of a railroad train whistle as it passes your crossing. Similarly, if a light source is approaching the observer, its color will be bluer than if the source were at rest, and if it is receding, its color will be redder. This is the Doppler effect or (in the last case) the red shift. The Einstein shift, in turn, arises from different causes—there is no motion of source with respect to observer—but the net result is the same.

If a ray of light originates on the surface of a star, for example, Einstein's theory assumes that the star's massive body holds it back, so to speak, by its gravitational attraction. This is equivalent to the stretching of the sound waves mentioned above. When the wave length of that light ray is measured in a laboratory, it is compared with that of a terrestrial light source produced by the same substance. But because the earth is less massive, the wave length of the terrestrial source is stretched to a much lesser extent, and the stellar source appears redder by comparison. This, in essence, is the gravitational red shift. Such an effect is difficult to measure in the case of the sun (although this has been done) because it is inextricably mixed with true Doppler effects, caused by motion of gases in the solar atmosphere. It has been measured successfully for the small, but very massive, companion of Sirius, It should be readily understood that the effect is opposite, and thus becomes a blue shift, when the observer's laboratory is located in a site where gravitational attraction is greater.
than at the place of origin of the source being measured. For example, such a blue shift would be detected if we could measure with great accuracy the wave length of a light source generated in a small artificial satellite, in comparison with a terrestrial source.

The third astronomical phenomenon predicted by General Relativity is the deflection of light rays by the gravitational attraction of massive bodies. Einstein assumed that, in its travel through space, a ray of light behaves like a stream of material particles. When the light rays coming from a star pass in the immediate vicinity of the sun, the particles are subject to the space curvature caused by the sun’s gravitational attraction and must therefore follow a geodesic. The net result is that the rays are slightly deflected (see diagram at left). To a terrestrial observer, the star appears slightly displaced from its true position. This effect is greatest (about 1.75 seconds of arc) for stars sighted near the edge of the sun, and falls off rapidly as the angular distance from the edge increases. For that reason, it can be observed only during total solar eclipses, when stars are visible in the immediate vicinity of the sun. The star field surrounding the sun is photographed while the eclipse is in progress, and again several months later when the sun has moved to another part of the sky: the gravitational displacement of the star images is determined by comparing the two photographs. Theoretically, stars other than the sun would cause similar deflections of light rays, but there is no convenient way of observing this. The existence of the Einstein deflection was confirmed for the first time from observations of the solar eclipse of May 29, 1919, a scant three years after publication of his General Theory of Relativity.

The theories of Einstein have been used extensively by modern cosmologists to construct—figuratively speaking—mathematical models of the universe. Although the existence of “island-universes” had been a matter of philosophical speculation for at least two centuries, it was only in 1925 that Edwin Hubble, astronomer at the Mount Wilson Observatory, obtained indisputable proof that the nebulae (now called galaxies) are vast stellar systems outside our own Milky Way. In 1929, by applying the principle of the Doppler red shift, he discovered that galaxies are receding from the Milky Way with speeds roughly proportional to their distances. This does not imply that the Milky Way Galaxy is at the center of the universe, but merely that the entire universe is in a state of expansion comparable to that of an immense balloon being inflated. Because all dimensions of the “balloon” are increasing simultaneously, any two points chosen at random inside it will appear to drift away from each other.

The Belgian G. Lemaitre had demonstrated in 1927 that one of the models of the universe that may be constructed on the principles of relativity happens to be an expanding one. It should be pointed out, however, that Hubble’s discovery of the red shift of galaxies does not necessarily prove the validity of Lemaitre’s model to the exclusion of all others. The only established fact in this respect is that, from observational data, one may be reasonably sure that the universe is currently in a state of expansion, and that relativistic theories are among those that are capable of accounting for this fact.

Models derived from the principles of General Relativity may be divided into two bread categories: the “big bang” models and the pulsating one. The first category, which includes Lemaitre’s, assumes that the age of the universe is finite (in the order of 10 billion years) and that the expansion started explosively from a highly concentrated state, or “primeval atom.” The others, on the contrary, consider that the age of the universe is infinite and that it undergoes successive periods of expansion and contraction, each one lasting many billions of years.

During the past decade, a number of models have been proposed, which are no longer based on the principles of relativity. The most famous of these is the “steady state” theory, which assumes that matter is continuously created in the universe, probably in the form of hydrogen atoms in the vast spaces between galaxies. These atoms are presumed to condense eventually into new galaxies.

Unfortunately, it is impossible to decide between these conflicting models because they postulate events—the birth of hydrogen atoms in intergalactic space, an explosion that happened aeons ago—which cannot be verified by observation. In a few hundred years, they may well seem as quaint as the stars on the goddess Nut of ancient Egypt.
THE SKY IN DECEMBER

From the Almanac:

<table>
<thead>
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<th>Phase</th>
<th>Date</th>
<th>Time</th>
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<tbody>
<tr>
<td>New Moon</td>
<td>December 7</td>
<td>6:52 P.M., EST</td>
</tr>
<tr>
<td>First Quarter</td>
<td>December 14</td>
<td>3:06 P.M., EST</td>
</tr>
<tr>
<td>Full Moon</td>
<td>December 21</td>
<td>7:42 P.M., EST</td>
</tr>
<tr>
<td>Last Quarter</td>
<td>December 29</td>
<td>10:57 P.M., EST</td>
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The sun will be at the winter solstice on December 21 at 9:20 P.M., Eastern Standard Time; winter will begin on that date in the Northern Hemisphere.

For the visual observer:

Mercury, in the morning sky for the first half of December, will be in superior conjunction on December 16 and will enter the evening sky on that date. As a result, it will be too close to the sun for observation.

Venus (−3.4 magnitude) will rise one hour before the sun on December 1 and 45 minutes before the sun on December 15. The planet may be observed as a morning star in the early part of the month, but its angular distance from the sun will diminish gradually. By the end of the year, Venus, like Mercury, will be lost in the sun's glare.

Mars (+1.5 magnitude) will be in conjunction with the sun on December 14 and will enter the morning sky on that date. Mars, too, is unfavorably located for observation in December because of its proximity to the sun.

Jupiter, in Capricornus (−1.6 magnitude), will set in the southwest at 8:45 P.M., local time, on December 1, at 3:00 P.M., December 15, and at 7:15 P.M., December 31.

Saturn, in Sagittarius (+0.3 magnitude), will be approximately 7° west of Jupiter during the entire month and will set about 45 minutes before that planet.

During the evening of December 10/11, the moon will pass about 2° north of Jupiter and Saturn. The lunar crescent will be only three days old at that time, and the two planets should be seen clearly in its vicinity.

The Geminid meteor shower will reach its peak on December 13. Its maximum rate is estimated at 50 meteors per hour (for a single observer). As its name indicates, the meteors belonging to this shower will appear to radiate from a point in the constellation Gemini.

New Year's Day:

Contrary to what might be surmised, there is no astronomical phenomenon corresponding to the beginning of the calendar year. As a matter of fact, January 1, itself, has not always heralded a new year in the Christian world. Until two centuries ago, March 25 played that role in England and its territories, including the American colonies. When England switched from the Julian to the Gregorian calendar (in 1752), it concurrently adopted the western European practice of beginning the year on January 1. For a time after the change was made, and in order to avoid confusion, dates within the overlapping period were written in both styles, thus: January 18, 1754/5.

It should be noted that the term "style" refers specifically to the date on which the year begins (Annunciation style for March 25, Circumcision style for January 1). In the English-speaking countries of the world, however, the expressions "old style" and "new style" are frequently applied to the Julian and Gregorian calendars, respectively.

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On the preceding pages, Mrs. Gossner offers the last in her 1961 series on the growth of cosmological concepts.
MAGNITUDE SCALE

- -0.1 and brighter
★ 0.0 to +0.9
★★ +1.0 to +1.9
★★★ +2.0 to +2.9
★★★★ +3.0 to +3.9
★★★★★ +4.0 and fainter

TIMETABLE
December 1 11:00 P.M.
December 15 10:00 P.M.
December 31 9:00 P.M.
(Local Standard Time)
EIGHT YEARS AGO we established a rhesus breeding colony at the University of Wisconsin's Primate Laboratory to provide a steady supply of healthy, newborn monkeys for intensive study of learning and intellectual development from the day of birth until attainment of full capacities. Only by controlling the environment from birth is it possible to trace development under constant conditions. We controlled the monkeys' environment — and, consequently, their life experiences—by removing each baby from its mother within 6 to 12 hours of birth and placing it in a wire cage in a nursery where it could see, hear, and communicate with other babies but not make bodily contact.

During the early months, the babies were treated much like human babies, with bottle feedings, supplements, and gradual transition to solid foods. The babies thrived. Mortality was much lower than for babies raised by their own mothers, and illnesses were few. They were a strong, healthy group of monkeys, and 55 of them underwent regular daily testing on a variety of learning and perceptual tasks. At a year of age, the rhesus young were promoted from the nursery to larger, individual cages in another room, where they continued as subjects in the developmental project. It was planned that, after they finished their jobs in this long-term project, they would be consigned to the breeding colony to provide a steady supply of healthy babies for other research, including the tracing of affectional development from birth onward.

We had not expected to use these particular animals in the analysis of affection. However, they have accidentally proved to be very helpful as subjects. At the same time, they have proved to be almost worthless as

A Study of Animal Affection
Deprived of mothering and play, monkeys remain infantile

By HARRY F. HARLOW and MARGARET K. HARLOW
IMMATURE MALE RHESUS SHOWS STEREOTYPED BEHAVIOR OF THE
emotionally disturbed (handclapping, above). This monkey,
now over three years old, grew up with a manikin "mother."
Often withdrawn and passive, these animals cannot be bred.
breeding stock: these healthy, educated, laboratory-reared monkeys simply have not been productive as parents.

But before we go into the group's unanticipated procreative problems, we need to introduce the reader to our researches on love and affection—studies still in progress although initiated over five years ago.

Our first experiments on love and affection were designed to discover the variables that tie infants to their mothers: that is, the infant-mother affectional system, the first to appear in the development of the individual—monkey, human, or sub-primate. For this research, a second group of newborn monkeys was isolated. Because monkey mothers, like human mothers, vary greatly in behavior toward their infants—ranging from highly devoted and protective to neglectful and even abusive—we controlled this "mother variable" by fabricating substitute mothers whose frames were made of wire, sheet metal, and wood. All the "dummy mothers" gave physical support. Some provided nourishment by means of formula fed through a nipple protruding from the chest; some provided the comfort of a soft, textured skin—a terry cloth body covering. Later experiments introduced mother models with new attributes, all studied under carefully controlled conditions; some of these "mothers" had rocking motion, some provided body warmth, and some varied the angle of incline.

A few of these early studies have already been described (Natural History, May, 1960). In summary, our data led to the inescapable conclusion that contact comfort, through softness and warmth, was the crucial factor in the development of the infant's love for its mother. When the animal is still very immature, it prefers a mother that also provides nursing, rocking motion, and a less steep incline than our standard models. Later, when the baby moves about with ease, these added provisions are of no importance at all: the baby divides its time equally between cloth mothers with and without an additional feature other than warmth, even though it has been reared from birth with access to both models.

In all, about 90 infants reared on such artificial mothers—one mother or two mothers each—have reached maturity. Like their cage-raised, motherless relatives, they are healthy, strong animals and have been consigned to the breeding colony. But these animals, too, are producing few babies, in spite of intensive efforts to rescue them from their celibacy.

Even before we discovered that we had raised large numbers of abnormal animals, we had already undertaken studies of three other affectional systems of monkeys: infant-infant (or peer) affection—the attachment of young monkeys to others of their age group; heterosexual affection—which appears in complete and full form in adolescent and adult animals; and the maternal affectional system, or mother-infant affection. Large bodies of data are already available delineating the development of the infant-infant system, and there are sufficient results on the next two systems to enable us to draw some firm conclusions about them and about the affectional deficiencies in both cage-raised and manikin-reared babies.

The infant-infant affectional system is the second to appear in the individual's life span, and we have studied it in several experimental situations. Our initial infant-infant study introduced groups of four babies each, one group at a time, into a playroom. Inside were a platform, a ladder, a rotating wheel, and flying rings, which enabled the animals to move about and exercise in a three-dimensional world. There were also many toys and puzzle devices. The groups were together daily for 20 minutes in the playroom but lived in individual cages with cloth mothers the rest of the time. During the course of more than 18 months, we found a series of stages in the infants' play and interrelationships.
The first stage was presocial, during which the babies explored and manipulated all the objects in the room, including other monkeys, but did not engage in any play with each other. It is highly similar to the first play stage of human infants and young children. The next stage was rough-and-tumble play, during which the babies romped, wrestled, rolled, and tussled in furious encounters (although no animal was ever hurt in this play). The third stage, approach-withdrawal play, was characterized by pairs of monkeys chasing each other back and forth without necessarily engaging in any physical contact. The fourth stage has been described as integrated play: it involved both rough-and-tumble and approach-withdrawal and frequently gave rise to brief play patterns of “frantic frenzy,” incorporating any and all of the objects in the room (photo, left).

The fifth stage, aggressive play, began to appear near the end of the first year. It was characterized by biting and pulling but involved little or no bodily hurt. Gradually, this changed to a stage of true aggression, in which the animals established their dominance positions in the group. But no serious injury occurred, probably because the monkeys had gained skills of evasion as well as attack during the more relaxed and carefree stages of infant-infant affection. Characteristically, one monkey grabbed another’s fur, or ear, or leg with hand or mouth, pulled, twisted, and tore, and sometimes even drew blood. Such behavior gradually reduced; subsequently social play ceased. Thus social order and status were established, as in a neighborhood play group, and at the same time, firm affectional bonds, formed earlier, remained.

The third affectional system, chronologically, is the heterosexual system, and it develops from early infancy through maturity. Like the other affectional systems, it goes through a series of stages, and at least three can be clearly identified: an infantile stage; a stage of sex play; and a stage of mature sexuality. In the infantile stage, overt sex behavior is relatively limited and the patterns of sex behavior are typically fragmentary and incomplete. However, from the first month of life onward, little males and little females could be identified in terms of the frequency of certain selected patterns of behavior. Females show increasing frequency of passive behavior while males show an increasing frequency of aggressive behavior, as indicated by patterns of facial and bodily threat. Even though sex behavior is fragmentary and incomplete, there is a progressive tendency for the male animal to show patterns of attempted mounting and thrust and for the female to show the patterns of crouching and presenting. From six months onward, there is very little overlap between the sexes in these specific patterns.

Among the wild-raised and mother-raised rhesus monkeys at the laboratory, full-blown, normal sex patterns are relatively frequent during the second year of life, before either sex is mature. There is no evidence for any biological latency period. With mature partners, the basic patterns are performed in sequence (and with completion when the females reach maturity in the third year of life and the males in the fourth year).

The fourth affectional system that we studied is that of maternal affection. Primarily we observed this system in our playpen situation, which consists of four large, wire-mesh living cages, one for each mother-infant.

Cage-raised female, deprived of both real parent and manikin, is example of severe neurotic disturbance. Only one such cage-raised female has conceived.
pair, and four playpens. Each cage-playpen unit has an opening large enough to permit free passage of young monkeys but too small for the mother. The panels between adjoining playpens are raised one hour a day, permitting pairs of babies and, subsequently, all four infants to interact.

The maternal affectional system can be traced through three stages: a stage of attachment, a stage of ambivalence, and a stage of separation. The attachment stage begins at delivery, or shortly after, and continues for about 90 days. (Typical maternal behavior in this period is shown in the photograph on p. 43, left.) During the first several days after delivery, many (and probably most) mothers show attachment and affection toward all baby monkeys and will adopt or even steal other babies if given the chance. Subsequently, most mothers show strong attachment and protective responses only to their own (or previously adopted) babies. Although one of our mothers has been kind and acceptant of all babies throughout the first year in our playpen situation, she appears to be exceptional. The other mothers have all become aggressive toward other infants, and this aggression has been noted to coincide with the time the babies start engaging in rough-and-tumble play. While the babies are actually wrestling, the mothers watch closely and suffer, as indicated by growling, snarling, and shaking the cages, and should a retreating baby come into the wrong mother’s cage, it is apt to be forcefully ejected. The mother of the ejected baby then shows disapproval of the other mother by still fiercer growls and cage-shaking.

From 90 days on, the protective and comforting responses of the mother to her own infant decrease and the punishing responses increase: this behavior characterizes the stage of ambivalence. The mother does not really abuse her baby, but from time to time she resists its approaches and its demands upon her time and person in a decisive and vigorous manner. Throughout this period, the baby continues to use the mother as a source of security, and at night mother and baby are in close physical contact. It is at this point in our studies of the affectional systems of the monkeys that we may relate our findings to human behavior. It has become apparent through the years that basic to the problems of many neurotic and psychotic humans are abnormalities in affectional relationships originating early in life. Case histories suggest that the infant’s failure to form satisfactory affectional relationships—particularly with the mother and often with the father—can lead to subsequent failure to find satisfactory relationships with parent substitutes and with peers first, with mates later, and with offspring still later. Fortunately, not all emotionally deprived infants and children show this sequence of problems, but so many of the mentally ill do that it is of interest to attack the problem experimentally.

One cannot, of course, use human subjects, but it is especially fitting to use monkeys, for these animals closely resemble man. The goal is first to demonstrate that normal, healthy babies, born to behaviorally normal monkey parents, can be rendered neurotic or psychotic by controlling their early emotional and social experiences. This could help to establish indirectly that mental illness is not necessarily determined by constitutional abnormalities or inherited weaknesses, as some still believe. Beyond this, through success in producing disturbed animals, we can trace effects on subsequent generations of animals raised by the disturbed animals. The over-all goal is to provide data that might enable us...
DAILY observation for as long as six or seven years has revealed various behavioral aberrations in the motherless group, behavior not commonly noted in monkeys captured in the wild or those raised in group-living situations. Many of these “deprived” monkeys, especially the older ones, sit passively in their cages and stare vacantly into space, paying little attention to the monkeys in neighboring cages or to the activities of workers in the room. Some show peculiar stereotyped behavior such as clapping their head or body in their arms and rocking back and forth for long periods of time. Others show patterns of self-punishment, such as seizing an arm with the mouth and tearing at the flesh until blood flows. This is all behavior that one can observe repeatedly in severely withdrawn patients in mental institutions.

Exposed, in test situations, to each other and to monkeys of their own age captured in the wild, these motherless animals have been consistently less responsive to other monkeys except for fighting, in which they engage freely. Unlike normal animals, they avoid opportunities for social contacts such as are customary among peers.

In breeding attempts, the motherless females have been paired with patient males from the breeding colony, and the motherless males have been paired with experienced females. In several years of repeated trials, no motherless male has ever achieved intromission, although these animals have shown sexual excitement. Often they have engaged in violent assault against the female, forcing us to remove the male. After years of testing, one motherless female has to date been impregnated (more a triumph of the male than the female). Generally these females have avoided the males or assaulted them, showing only fragments of the normal sex patterns.

The dummy-mothered monkeys have been somewhat less disturbed, as one would predict on the basis of degree of deprivation and age, but their behavior nonetheless has been distinctly abnormal. They tend, like the motherless monkeys, to sit passively in their cages, staring vacantly and paying little or no attention to other monkeys or to people. They rock, suck their body parts, and ex-
habit both stereotyped patterns and self-aggression, but in general they do so in lesser degree and less frequently than do the motherless monkeys. They are a younger group, however, and may show more severe aberrations as they grow older.

The majority of the cloth-mothered animals are sexually mature. Yet none of the males has achieved any semblance of normal sex behavior, even though they show sexual excitement during mating opportunities. The females have been slightly more responsive, no doubt because their role is relatively passive compared with the male's, although success has been achieved only with three and only after numerous exposures to selected breeding males.

Recently we have produced bizarre behavior in eight monkeys in situations we call “self-mothering.” Four infant monkeys were placed as pairs in standard living cages, and four other infant monkeys were placed as a group in a considerably larger cage. The monkeys living as pairs have shown a progressive tendency to maintain a tight ventral clasp similar to the contact clinging of baby monkeys to real or cloth mothers (photo, p. 52). We call this “together-together” behavior. These two together-together pairs have been tested in the playroom, from birth onward, for more than a year and have shown almost no play. When they were approaching their first birthday, they were re-paired, kept in their cages for three weeks, and then reintroduced to the playroom. They showed no sign of affection for their original partners and made no effort to contact them. Instead, they maintained their tight clasp with their current partners.

Returned to their original partners for three weeks and then retested, they rapidly sought out and clung to these original partners, their then-current living companions. These animals appear to be arrested in their affectional development at the early attachment stage seen in our infant-mother studies. It seems likely that contact clinging, established between newborn monkeys, destroys infant-infant—and probably all subsequent—affectional development.

The behavior of the group of four self-mothered animals differed somewhat from that of the two pairs. Instead of going into patterns of tight ventral contact clinging they tended to line up in a row with one monkey in the lead, the second clutching the leader's back, the third clutching the second's back, and the fourth hanging on or close to the third, “choo-choo train” pattern (photo, p. 53). From time to time, one or more of them would break away and roam about the enclosure, but soon it would be shackled by the others and find itself dragging two or three cagemates. Tested in the playroom, they showed practically no indication of any play behavior. Their affectional and social behavior seems, like that of the self-mothered pairs, to be arrested at the early infantile attachment stage.

No member of the together-together pairs and none of the “choo-choo foursome has shown any sign of the development of heterosexual behavior. We are almost certain that, when they attain puberty and adulthood, they will be as sexually handicapped as the monkeys previously described.

At the present time, we have very limited data on the effect of early mothering experience on the child's maternal affectional pattern, but we have discovered enough to present some fairly suggestive findings. As already stated, through the use of patient measures, one cage-raised and three cloth-mothered females were successfully bred. All are now raising their babies in a playpen situation.

The first mother paid no attention whatsoever to her baby after it was born but, instead, would sit in the cage staring vacantly into space. She gave no evidence of protective maternal responses either when her infant was threatened or when the experimenter took the baby away several times a day for artificial feeding. As soon as the baby could locomote it struggled desperately to establish normal contactual relationship with its mother. It would climb on its mother's back only to be brushed away by the mother as if she were brushing off flies. When the baby persisted, the mother would crush the baby's face or body down on the floor.
of the cage with her hand or foot while either looking at the infant or staring blankly into open space. The behavior of the second mother was similar; she ignored her baby after birth and often struck or bit it until the infant screamed in pain.

The third mother initially ignored her baby or indulged in abuse; indeed, she was the most brutal of the three. However, this baby, through persistence, was able to establish a nursing relationship with the mother from time to time. After the first few days, we were not forced to feed it.

This in no way means that the mother was normal, since the baby succeeded in making contact with her only a fraction of the times it tried. Even when it succeeded, the mother treated it in a passively acceptant manner and showed only very mild defensive reactions when the baby was threatened. Normal mothers clasp their babies tightly and show violent threat behavior when an outsider comes near their cage. Any belief that maternal affectional patterns were really formed by this third mother was dispelled during most observational periods. Very frequently the mother would either sit on the cage floor or hang by her feet from the ceiling and strike the baby repeatedly with her open hand without provocation of any kind.

The fourth mother is somewhat more passive than the others. Although she has abused her baby, she is less violent and nurses her baby.

Data derived from these atypical mothers are most compelling. We cannot be sure, of course, whether their failure to show normal maternal behavior stems from their motherless (or inadequately mothered) infancy, from their lack of association during the first years of life with other infants and young monkeys, or from both factors. We only know that these monkeys without normal mothering and without peer affectional relationships have behaved toward their infants in a manner completely outside the range of even the least adequate of normal mothers. They constitute our most dramatic discovery to date in the production of abnormal affectional behavior, and we wait with eagerness to trace their subsequent personality development and the personality development of their unlucky babies as they grow, mature, and, in the case of the females, become mothers themselves. We have failed in some efforts to make mechanical rejecting "mothers," but we have triumphed without intent in flesh-and-blood ones.
Endangered
Relic Trees
The West's rare trees are becoming rarer
By PAUL D. KILBURN

It is scarcely surprising that California, the state with the greatest ecological variation in the United States—where habitats stretch from below sea level to over 14,000 feet, and climates vary from desert heat to alpine cold—should possess a world-famous aggregation of tree species. Many of these trees are confined within the state's boundaries and, in fact, more than 1,400 of the total vascular plant flora (some 4,000 species) are restricted to the state. Others spill over, but only slightly, into the geographically similar parts of neighboring states and Mexico.

Many of these endemic plants are extremely rare, found only on a particular island, desert, or mountain. For years, some desert annuals exist only as viable seeds, awaiting sufficient moisture to break their dormancy and enable them to grow and blossom. But better known than these annuals are several tree species that cling to life precariously in small areas. These relics, remnants of the former widespread forests, emphasize that extinction is always a possibility and that a slight change in the environment could easily eliminate them. Such has often been the case in the past, for extinction has been a corollary to evolution. While the number of plant species is enormous (upwards of half a million), many more than this number became extinct as natural selection weeded out those species that could not adapt to a changing environment. But such extinctions took place slowly; organisms had but to adapt gradually to a changing environment in order to remain alive.

Today a new environmental force, acting with extreme rapidity, faces all biota—namely, man and his actions. This force has the ability both to eliminate and to propagate. With wisdom and foresight, man can be the means of insuring survival of the isolated stands of trees discussed in this article; with carelessness, as has been the case all too often in the past, he can be the means of their total and irreparable destruction.

The list of rare California trees is too long for this article—many of the rarer ones, such as gowen cypress and oracle oak (a hybrid that is also found in Oregon) are not included. Those that are discussed are the more famous, and often possess features of particular interest in addition to rarity. Not all are botanically rare in the sense that they stand on the verge of extinction, but all those discussed are relics with narrow ecological distribution patterns. It is not absolute extinction they face, for individuals grown from seed adorn parks or streets throughout the world, but rather extinction in their native habitat. These are truly relics.

The star of California's relic trees is that twisted coastline rarity, the Monterey cypress (Cupressus macrocarpa). Fame has come to this species for its location on the seacoast of the Monterey Peninsula, about 100 miles south of San Francisco. The number of wild individuals of this tree is in the thousands, all growing within a few miles of each other on the rocky southern coast of the peninsula and Point Lobos, a few miles to the south. Here, they present a fitting adaptation to the strong, constant sea wind, molding themselves to the rugged rocks. This cypress is a short tree; the tallest is sixty feet, and its wide-spreading shape is much more typical of an oak than it is of a conifer. Dense foliage is produced by a thick growth of branches extending to the ground where the trunk may be three feet thick. Although a poor timber tree, it makes an ideal windbreak near the ocean. Unfortunately, it apparently requires the sea fog to flourish, and its distribution is limited.

The cypress genus possesses several species nearly as rare as this tree. In fact, few other genera of plants are so uniformly restricted. None combines the picturesque habitat, unique...
Monterey cypress, bent to grotesque, streamlined form by the constant gales from the sea, forms windbreaks along California shore, but declines inland.

growth form, and accessibility of the Monterey cypress, and hence they remain unknown to the layman.

Two species of the formerly widespread genus Sequoia survive today in California. The coast redwood (S. sempervirens), the world's tallest tree, occurs beyond California for some eight miles into southern Oregon, and is not technically confined to the state. This species, an abundant tree along California's northern coast, is still logged commercially. Valuable and enormous, it is a relic of the former widespread sequoia forest that once grew as far away as Greenland and Alaska in past geologic times.

Many redwoods tower 300 feet or more, but the tallest of this race of giants is found in the heart of the redwood belt, far north of San Francisco, at Dyerville Flat. Here the Founders Tree towers 364 feet above the ground, yet so tall are its neighbors and so accustomed to loftiness is the visitor, that this unbelievable height does not seem extraordinary from below. The diameter of the largest trees often exceeds 10 feet. Sometimes they attain 15 feet and, rarely, 20 feet, with a maximum of 22.5 feet; yet these girths rank well below those of the Sierra big trees.

Ecologically, the redwoods are confined to areas that receive the summer fog belts that roll in from the Pacific early in the afternoon, shrouding the tall giants in a cool, moist blanket until the late morning sun burns the cover away. Because of this dependency on ocean fog, the tree is never found more than 10 miles from the
Coast redwood, abundant on northern shores of California, is also found in Oregon and lumbered commercially. Those above grow along the Eel River.

Pacific, and usually it is much closer. Thus, a narrow belt of redwoods extends from the Oregon border for some 450 miles down the northern coast of California, breaking down into scattered and separated ravine-bottom groves south of Big Sur, near the extreme southern range.

The work of preserving virgin stands of redwoods from logging for all time was undertaken jointly by the Save-the-Redwoods League and the state of California. As the result of this unified, co-operative venture, 65,000 acres of redwood land have been preserved. Much of this land is in small groves and parks near major highways, available for the enjoyment of travelers for many years to come. While logging the remainder of the stands goes on at a rapid pace by a
highly organized industry, man can relax in the knowledge that his children will have many stands in which to wander, and that redwoods will provide multiple use—lumber, recreation, and solitude—for years to come.

A close relative, the Sierra redwood (S. gigantea) or big tree, the largest living thing, is a true relic of the western slope of the Sierra Nevada mountain range at elevations from 4,000 to 8,000 feet. The tree occurs in scattered groves over a north-south span of 250 miles. While not facing immediate extinction, it is a relic of wider distribution in the past. The big tree is probably the world's most impressive and famous tree. Although not one of the tallest trees, its unbelievable girth makes the observer's first impression one of disbelief. The tree dominates a forest in which wildlife abounds. It is an ideal spot for hiking and for photography, as the widely spaced trees and sparse undergrowth leave abundant light for pictures. Young sequoias are common here, for the tree reproduces well on exposed mineral soil, such as paths and road cuts, and the groves promise refreshment to visitors for many years to come.

Since the discovery of these groves in 1852, man has had a decided effect on the future of the trees. Of prime importance was placement of most of the groves in public ownership, where they can be protected and easily visited by everyone. This ownership pattern ended destructive logging on public land, an activity that aroused public opinion. Unfortunately, logging still persists on private lands.

We do not know the effect of the virtual elimination of fires—which have always been part of the natural environment of these trees—on their future. Nearly all the larger trees attest to former fires with charred bark and deep scars. Cessation of these fires has allowed a dense forest of white firs to spring up in many places, preventing young Sierra redwoods from becoming established. More research on the effect of purposely set, light fires to encourage sequoia reproduction is needed. Finally, man's trampling of the soil around famous trees and in the better-known groves may adversely affect the health of these giants. The Park Service, taking cognizance of the problem, has enclosed the most popu-
Torrey pine may be the world's rarest tree. It grows wild north of San Diego and on Santa Rosa Island. Today, only 3,000 individuals are known to exist.
lar trees with fencing. This protection is needed for many others, however, as trampling has compacted the soil a foot or more around some trees. In the future, healthy stands will require close and intelligent management.

Several unusual pines, conifers of the genus *Pinus*, occur among those growing wild in California. Ranging in size from the short, squaty pinyon pine of the desert border to the tall, majestic sugar pines of the Sierra Nevada, this group is perhaps the most conspicuous of California's tree cover. Like conifers throughout the Northern Hemisphere, the pines grow in nature's ecological slums. Sturdy and abundant, they are found at desert fringes, on bare rocks, and at the highest timber lines.

Two of these pines evoke unusual interest—one bordering the Pacific shores, the other growing at high timber line. It is the former, a tree clinging to the bluffs of the Pacific at Del Mar, just north of San Diego (it grows wild in only one other place—Santa Rosa Island, just off Santa Barbara) that lays claim to the title of the world's rarest tree. Here the Torrey pine (*Pinus torreyana*), represented by only about 3,000 small, twisted individuals, faces the steady and forceful sea breeze from the Pacific. This number appears large in comparison with figures on certain rare animals, yet in fact it is extremely small when the future of the species is at stake. A plant has no means of moving out of the way of fire or severe storms that could eliminate its wild populations. This tree is certainly on the verge of extinction.

Many of the pines near Del Mar are protected within Torrey Pines State Park and what a wild, magnificent collection of beach and coastal bluff flora is found there! The pines persist in gullies and ravines leading oceanward and dominate the vegetation, although few exceed 30 feet in height. Surprisingly, when planted in protected places the Torrey pine is majestic, straight, and fast growing. Thus we see that the growth form of this pine is obviously influenced directly by the environment.

But it is a relatively abundant pine, one found in several western states, that in California reaches its greatest age and becomes the "oldest living thing" in the world——the bristlecone pine (*Pinus aristata*), growing at timber line in the White Mountains near the Nevada border. Here, in the rain shadow of the Sierra Nevada, at 9,000 to 11,000 feet, occurs one of the strangest forests in the world. Its age and appearance makes discussion of the pine appropriate, even though it is not rare. The eerie woodland it dominates consists of very open stands of the massive, short tree atop the dry, rounded mountain-tops. The needles of the bristlecone, although in clusters of five, are a mere one or two inches long, and are indicative of a long-continued adaptation to its high, dry habitat. The cones bristle, as the name suggests, and cluster easily within reach on all but the largest trees. Tree size is deceptive here, for the growing season is short and a tree ten feet tall may be seventy-five years old. The oldest veterans may be but thirty feet tall, with diameters two feet at breast height.

Age is evident in every branch of these trees; looking at them, one can almost feel the brunt of the severe winter storms the bigger trees have withstood. Many are dead except for a narrow strip of bark and living tissue leading from the roots to one remaining branch. The most impressive sight in the entire area is the aptly named Methuselah Lane, a steep slope on which many of the trees are more than 4,000 years old, and where the oldest one yet sampled, more than 4,600 years of age, still grows. Trees on this slope are often more dead than alive, yet stand silent guard over many fallen but undecayed individuals. Such falls represent centuries of accumulation, for decay proceeds very slowly on the rocky surface.
Youth is common in many of these forests, and young seedlings, two or three feet tall, are scattered about frequently. It is evident that although some mountainsides consist entirely of dying monarchs, most areas possess enough young trees to maintain the forests for a long time.

A perplexing feature in the forests is the presence of charcoal and fire scars on most of the old tree trunks. The open character of the trees and sparseness of the undergrowth make one wonder how such fires could spread, and what possible influence this has had on the distribution of the forests. Do the scars mean simply that the undergrowth was once shrubby, but has been killed by repeated burnings until only tiny annuals and rosette plants now exist? Does it mean that the absence of seedlings in some areas is the result of repeated fires? Answers to these questions must await more precise studies, including those at the Laboratory of Tree-Ring Research of the University of Arizona.

The area including most of the California populations of bristlecones lies within the Inyo National Forest and is, of course, protected by the federal government. Already, improvements in the roads and campsites are under way and the area will certainly be visited much more frequently in the future. And visited it should be, for the view from these mountains across the Owens Valley to the rugged Sierra Nevada must rank as an outstanding scene in a state possessing many breath-taking views. One may absorb many lessons here in the solitude of what seems to be the top of the world. Particularly forceful is the wonder one feels in seeing such weird forest beauty in this harsh habitat. For the wind is strong and continuous, an unrelenting factor eliminating all but the best-adapted plants.

One more tree remains to be discussed—the picturesque desert fan palm (Washingtonia filifera). This, California's only native palm, is not confined to the state. for a few are found in western Arizona and several in Baja California, but its unusual appearance and habitat, and its scattered distribution deserve mention. This—incidentally, the only palm native to the western United States—occurs in Southern California on the fringes of the low, hot Colorado Desert, which surrounds the Salton Sea. Here, usually in canyons and along streams issuing from the mountain ranges, the palm appears to be making its last stand against an increasingly hostile climate. In California, these tall, stately trees normally wear a thatched skirt of dead leaves that reaches nearly to the ground, and groves of these palms present a memorable sight. Groves vary in size from a few to many individuals depending on the number and size of mountainside streams or springs.

One of the most extensive views of these trees and their habitat can be seen by looking east from the Palmito-Pines highway, State Highway 74, some 3,000 feet up in the San Jacinto Mountains, overlooking the Coachella Valley. Far off in the distance rise the Little San Bernardino Mountains and below them are the Indio Hills. The palms appear as widely separated patches of green, dotting the base of these hills for miles. Closer approach reveals that they occur along the notorious San Andreas fault in places where streams and gullies dissect the hills. Here, exposed to the full blast of the desert sun on the south-facing slope, the palms grow in one of the world's most rigorous climates.

One can approach many of the groves readily, but the close-up view is often disappointing, for most of the trees have had their thatch burned off by man-made fires, and only charred trunks can be seen. Fire is a major enemy, since the thatch is highly flammable and burns with such heat that the terminal, leaf-producing area is often killed and the tree dies. Those that survive remind one of shorn sheep, differing from those animals in that they never regain their cover.

Most of the trees are unprotected on private lands, although the largest grove in Palm Canyon, just south of Palm Springs, is owned and managed by the Santa Inez Indians. A few small groves are under National Park Service jurisdiction in the Joshua Tree National Monument. The trees do reproduce, however, and the occurrence of some seedling palms will insure the species' continuance for some time under natural conditions.

Both the age of the oldest and their unknown history provide the palms with an aura of mystery. No one has yet determined how old the trees are, for these monocots lack a cambium and hence have no annual rings. Another area of interest lies in their discontinuous distribution, for the scattered groves suggest that they once had a connected distribution pattern under a more beneficent climate. Verifications of this feature and of the
trees' ages await further investigation.

Probably no other area of comparable size anywhere in the world possesses so many rare and interesting trees as the state of California. Here are found the world's tallest, bulkiest, oldest, and probably rarest trees. All are in magnificent natural settings and, fortunately, some of each grow on publicly owned and managed land. But all are accessible to the automobile. With today's growing population and vastly increased mobility, such biological phenomena will receive increasing numbers of visitors. Seen they must and should be, for their value to man is immeasurable.

But this unusual environmental force—man—also creates vast changes so quickly that three lines of activity have been urged. First, much more of our flora and fauna—not alone these unusual trees—must be preserved in parks and wilderness areas for future enjoyment and study. Second, active research into the historical development and ecological relations of many of these plants is needed before changes brought about by fire protection and increased human use make such studies difficult. Third, aided by the knowledge gleaned from such research, active management—not a "locked gate" policy—may be needed to insure their future.

Desert fan palm shows thatch effect of dead fronds on trunks. The greatest threat to continued existence of trees is extreme flammability of this thatch.
THE TOWN OF DELFT, in the Netherlands, is particularly famous for two things: one is the celebrated blue or brown pottery covered with figures in white glaze; the other is Antony van Leeuwenhoek. It was Leeuwenhoek who, in 1675, introduced to a startled scientific public the world of the infinitely little—of the microscopic animals and plants. This great Dutch amateur microscopist drew and described a one-celled animal now known as *Vorticella* and many of his subsequent discoveries of these creatures were so accurately depicted that they may be identified today as to genus or even species.

The huge Dutchman, with hams of hands, centred to grind minute lenses and mount some of them in metal plates, therewith opening up the whole of the microcosmic world. He discovered bacteria, spermatozoa, yeast, red blood corpuscles, the construction of muscle, bone, and other body tissues, and a host of additional subjects.

Today, Leeuwenhoek's discovery of *Vorticella* and others of his "little animals," has blossomed into the important science of protozoology. There are some twenty-one major divisions of the animal kingdom, and the lowest of these is the Phylum Protozoa, consisting of those animals whose whole body is but a single cell, or sometimes a colony of cells. At one time, zoology stressed the simplicity of the Protozoa; now one speaks of their complexity, for some of them, as *Paramecium*, exist as single cells that are far more elaborate than any cell of the human body. For instance, in an individual animal, such as the *Amoeba*, a single cell with a nucleus and not much more, can do all of the basic things that a man can do! It moves about; it examines prospective food particles, accepting some and rejecting others; it digests these and uses the energy thus acquired for its own purposes; it avoids harmful objects in its environment; it respires, excretes, and reproduces.

The microscopist finds in this field one of his most important chapters. After classification has been mastered and some dozen or so forms known to the point of familiarity, a study of their lives, behavior, and habits may be undertaken, with experiments on their physiology.

Inevitably, their classification must come first. Protozoa are broken down into four classes, based on the structures they develop for locomotion. There may be protrusions of the cell substance, blunt or fine, known as pseudopodia (false-feet), which flow out, pull the animal forward, and then melt back into the general cell cytoplasm. They are temporary and are put forth now here and now there; some of them fork or branch and make a network, with their neighbors. Protozoans that possess pseudopodia are members of the Class Sarcodina (sarcodes means flesh), and the familiar example is amoeba.

Many protozoans are provided with one, two, or a few long whiplike processes, the flagella. Each is an extension, usually from the forward end of the cell; a fiber covered with a thin sheath. Flagellum means "little whip," and that is just what they are, as their vibrating movement results in pulling the animal forward in a straight line, an undulating line, or a spiral. Protozoa equipped with these structures are known as flagellates and belong to the Class Mastigophora (whip-bearers). The classic example for study is *Euglena*, but because this organism contains chlorophyll it is claimed by the botanists as a one-celled plant. The fact is that many of the first plants, as well as the first animals, progressed by means of flagella.

Most highly specialized of locomotor organelles in the protozoa are the cilia, and animals having these are called ciliates. An example is *Paramecium*, of the Class Ciliophora (cilia-bearers). The word comes from the Latin for eyelash, because the cilia are fine, hairlike processes that either cover the entire cell surface, or emerge from certain restricted areas. They beat in unison with an effective stroke and a non-effective stroke, as when oars are used to row a boat. In this class are the most highly diversified and interesting of all protozoa.

A fourth group, the Class Sporozoa, are all internal parasites. They have no organelles for locomotion. The malarial parasite, *Plasmodium*, is the most widely studied example. However, the beginner confines his attention mainly to the first three types of Protozoa, since study of the Sporozoa is an advanced topic.
The collecting of protozans differs from that of most other animals or plants in that you cannot see what you are getting. The collector needs a number of large vials or small, wide-mouthed bottles, carried afiel in a haversack or compartment belt. Bulkier but equally serviceable are pint Mason jars or half-pint and pint milk bottles. Paste a blank label on each container on which to record the date and place where the contents were gathered. Almost any body of water, large or small, transient or permanent, city or country, may be selected as a likely site: the ocean, lakes, rivers, ponds, brooks, pasture rills, hog wallows, or water standing in tree holes, tusks, or the urns sometimes seen on gateposts or in cemeteries. Submerge the unstoppered bottle, and with the fingers poke in a quantity of muck, leaves, green scum (algae), and other water plants so that the container holds about one-fourth solid materials and the rest water. Use the lid of the jar or a discarded photo film as a scoop to include thin layers of the bottom sediment or surface scum. Water-lily pads are a good source for amoebas and their cohorts. If you can break through the ice near shore with a hatchet, you will be able to collect protozoans even in winter.

Back at the laboratory or your worktable, remove the lids and place the bottles on a window ledge or table where they will stand in moderate or diluted sunlight; too much direct sun will overheat the water and kill the organisms.

Dr. Corrington's column appeared regularly in Nature Magazine for nearly twenty years, and can now be followed in the combined magazines.

Each jar is now called a “culture” by extension from the use of this word in propagating colonies of bacteria. The water level can be recorded either by affixing a label on the outside of the container so that its top edge is flush with the level, or by using a glass-writing pencil. From time to time, as may appear necessary, add some of the same kind of water from which the original collection was made, to maintain this approximate level.

Begin a hay-infusion microcosm as follows: use a battery jar or other tall, straight-sided receptacle and fill it almost to the top with tap water. Allow it to stand uncovered for two days to permit the evaporation of excess dissolved oxygen in the water, then put in a generous handful of hay. Any kind will do, but timothy is preferred. Add a glass plate as a lid and stand this jar on the window ledge, as with your other collections. Keep a record of dates when begun, when ended, and for each examination in between, with lists of the organisms identified together with information on their rise, flowering, and decline. A similar preparation using lettuce is also good. After a few days these infusions will be teeming with many forms of life.

You will need one or more collecting tubes, which are rather like glorified medicine droppers. They may be purchased, but are simple to make. Take a length of glass tubing about the diameter of a medicine dropper, draw the center out in a flame to make a constric tion, file a nick across the middle of this narrow part, break off and anneal the break. Equip a one-foot length of such a tube with a rubber bulb about the size of a ping-pong ball. This is now a long-barreled pipette of the medicine dropper type that can reach to the bottom of your tallest culture and infusion vessels.

Take samplings of a few drops from the top surface of each vessel for one group of slides; from an inch below the top for another; and from the surface of the bottom sediment for a third. In each case, place one large drop on the center of a clean, blank slide and cap with a cover glass. Allow the cover glass to fall gently into place so the water can spread out beneath it to fill the whole area and thus float the cover. After a minute or two, the microscopic animals will recover from this rude transfer in their surroundings and will resume activity. First examine the slide under a low-power and then under a high-power objective, cutting down the light so that glare does not drown out the images. Some kinds of protozoans, as the amoebas and slower flagellates, may be kept under observation continuously, even under high power, but the swift forms dash about so rapidly that some means of quieting them is essential.
Within an average time of about thirty minutes, evaporation of the water from around the edges of the cover glass will have pulled the cover down upon the organisms, crushing them. As this is occurring there comes a time when their movements are so restricted that even the fastest among them will no longer be able to move and can be studied in detail under high power. To prevent their loss through crushing you may use an ordinary medicine dropper pipette to add a drop of the culture water exactly at the edge of the cover. The water will be drawn under by capillarity and rejuvenate the slide—but be careful that no water gets on the top of the cover.

You may decide to wash up this preparation and make a fresh slide. A better method is to use one drop of a 10 per cent fully hydrolyzed solution of poly-vinyl alcohol or one drop of methyl cellulose (trade name Methocel), either of which may be obtained from a biological supply house. To one drop of culture add one drop of "quieter," mix thoroughly with a toothpick, then add the cover. These chemicals have a high viscosity, which impedes the progress of the protozoa, without harming them. Another method is to place on a slide a ring of Methocel smaller in diameter than the cover. Place a drop of culture within this ring, then add the cover. The quieter gradually diffuses into the culture, bringing on a progressively slowing down of the animals. While such a slide is being prepared, especially if the eili- ate Paramecium is to be studied, you may also add a speck of finely ground or powdered carmine (rouge is a good source). The bright red particles will be ingested along with bacteria upon which the paramécium feeds, and the entire process of formation of food vacuoles and their circular movement round the cell (cyclosis) as digestion proceeds to a final elimination can be followed.

These cultures run through cycles. At one time the flagellates are dominant, later the ciliates; or one kind of ciliate is dominant, then another. A culture that appears to be dying out can be rejuvenated by adding new sources of food. For example, a number of investigators advocate using about one-tenth of a tablet of milked milk, mashed until powdered, then sprinkled on the surface. This brings about a rapid growth of bacte-eria, on which the paramécium and other protozoa will feed. Or add some strong boiled hay infusion of a dark brown color or a small amount of mashed yeast cake. The appearance of numbers of rotifiers in an infusion is a sign that the microcosm is running down. These multicellular creatures are so interesting that I shall devote an article to them. You will need a manual for identification, and one of the best is How to Know the Protozoa, by T.L. and F.F. John, Wm. C. Brown Co., Dubuque, Iowa, 1949. One of the best general text- books on the subject is Protoszoology by R. P. Hall, Prentice-Hall, Inc., N.Y., 1953. Collecting, mounting, staining, and studying methods are described in the writer's Exploring With Your Mi- croscope, McGraw-Hill Book Co., Inc., N.Y., 1955, illustrated with those species most likely to be encountered.

Sarcodians commonly observed in fresh-water cultures include the famous Amoeba, which is large as average protozoa go, filling the field under high dry (480X). It is colorless and appears as an irregular blob of jelly, flowing slowly along and putting forth pseudopodia which impede the protoplasm of the cell streams as it flows in to veseulate, so that a doughnut in front view, a football from the side, and is brown in color. This is because it is a shelled amoeba, with a circular opening in the lower sur- face through which it puts out pseudo- podia. Diffugia is another shell form, with a case made of sand grains cemented together in the shape of a hel- met, the pseudopodia projecting from the circular opening on the bottom.

Among flagellates, there is Peranema, a plastic little animal that spends much of its time changing its shape from tri- angular to oval to elongate. This cell moves forward in a straight line very slowly, stops and changes shape, then resumes locomotion again. It has two flag- ella, though one only is evident, the other being trailing and small. The ob- server will be mystified in that the main flagellum does not appear to move, so that the animal progresses by no discern- ible means. Under high power with the light very dim, or with dark-field or phase-contrast techniques, it may be seen that only the tip of this flagellum is mov- ing, vibrating rapidly—noisy by flashes of light—and effecting forward movement.

Astasia is a favorite specimen in the Class Mastigophora. It is a pear-shaped cell that moves forward steadily and slowly. It also has two flagella, the trailing one seldom seen, the other quite evident, long, and in active motion. Euglenoid is small, spindle-shaped, and much more rapid in locomotion than the two preceding. It is often present in enormous numbers, its bright green color making whole ponds or ditches green. The single flagellum is difficult to see. In dim light and under high power, movements of this little whip will be evidenced by flashes of light. At times the cell stops swimming, turns and coils upon itself, changing shape. The series of acts is termed euglenoid movement. At or near the base of the flagellum is a bright red eyespot, sensitive to light. The bulk of the cell is filled with chloroplasts—small bodies containing bright green
chlorophyll, a word that means “green leaf.” Chlorophyll is one of the most remarkable substances in the world. In the presence of sunlight as a source of energy, this pigment is able to synthesize carbohydrates from carbon dioxide and water. It is the primary manufacturing process for all foods of plants and hence, eventually, of animals. Because of their chlorophyll content, these protozoans will orient themselves with regard to light. If one side of the cover glass is dark and the other side is brightly illuminated, the euglenids will all gather in a band across the center, where the light is of proper intensity for photosynthesis to take place.

The microscopist finds his interest in the protozoa at its height, however, when he examines the ciliates, for they are an immense and diverse group whose members exhibit the greatest amount of specialization of which a single cell is capable. In the Class Ciliophora there are two main divisions, the Suctoria and the Ciliata. Suctoreans possess cilia only in the early stages of their life cycle. As adults they develop sucking tentacles, which they attach to the bodies of their ciliate victims, holding them fast in their struggles. These tentacles are hollow and through them the cell substance of the prey is sucked. All members are attached to some object in the substrate and most of them are stalked. Commonly is *Pedophrya*, frequent in freshwater cultures, which looks like an animated pin cushion on a stalk.

Ciliates were formerly termed Intusoria, since they are so abundant in invertebrates. *Paramaecium*, a member of the Order Holotrichida, known as holotrichs, in allusion to their possession of cilia of more or less uniform length and size over the whole cell surface. The *Paramaecium* is the Slipper Animal, referring to its shape, and is widely studied in all biology and zoology courses. It contains a macronucleus and one or more micronuclei, two contractile vacuoles—one in each half of the elongated cell—and a bulb in which an undulating membrane may be seen vibrating rapidly, driving food particles from the external mouth into the interior of the animal.

Other holotrichs likely to be encountered include *Fontonica*, which looks like a large and robust paramecium without the middle constriction; *Colpidium*, about the size of a paramecium, fast with the anterior end permanently bent at an angle, and often appearing in immense numbers in a hay infusion: *Colpoda*, small, kidney-shaped, with the mouth notched in the concave side; *Didinium*, the Paramecium Tiger, resembling a miniature turtle and, though smaller than its victim, it attacks paramecium and sucks the whole cell in through its terminal mouth; *Spatialia*.

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