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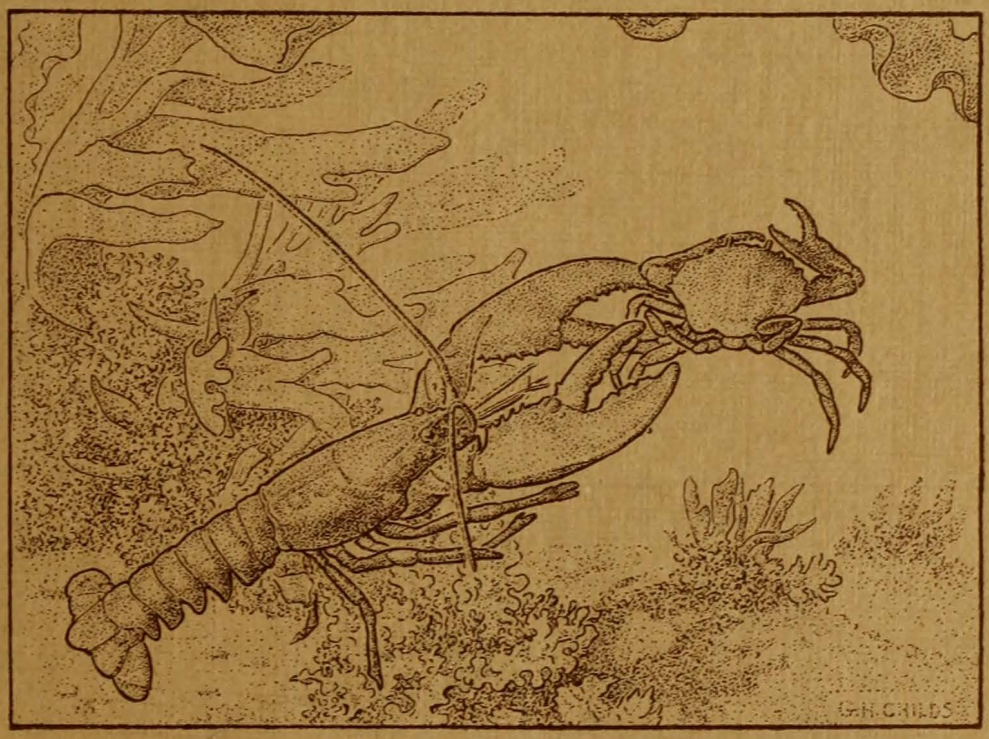
OUTPOSTS OF THE SEA



By ROY WALDO MINER

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OUTPOSTS OF THE SEA

ANIMALS OF THE TIDAL ZONE

By

ROY WALDO MINER

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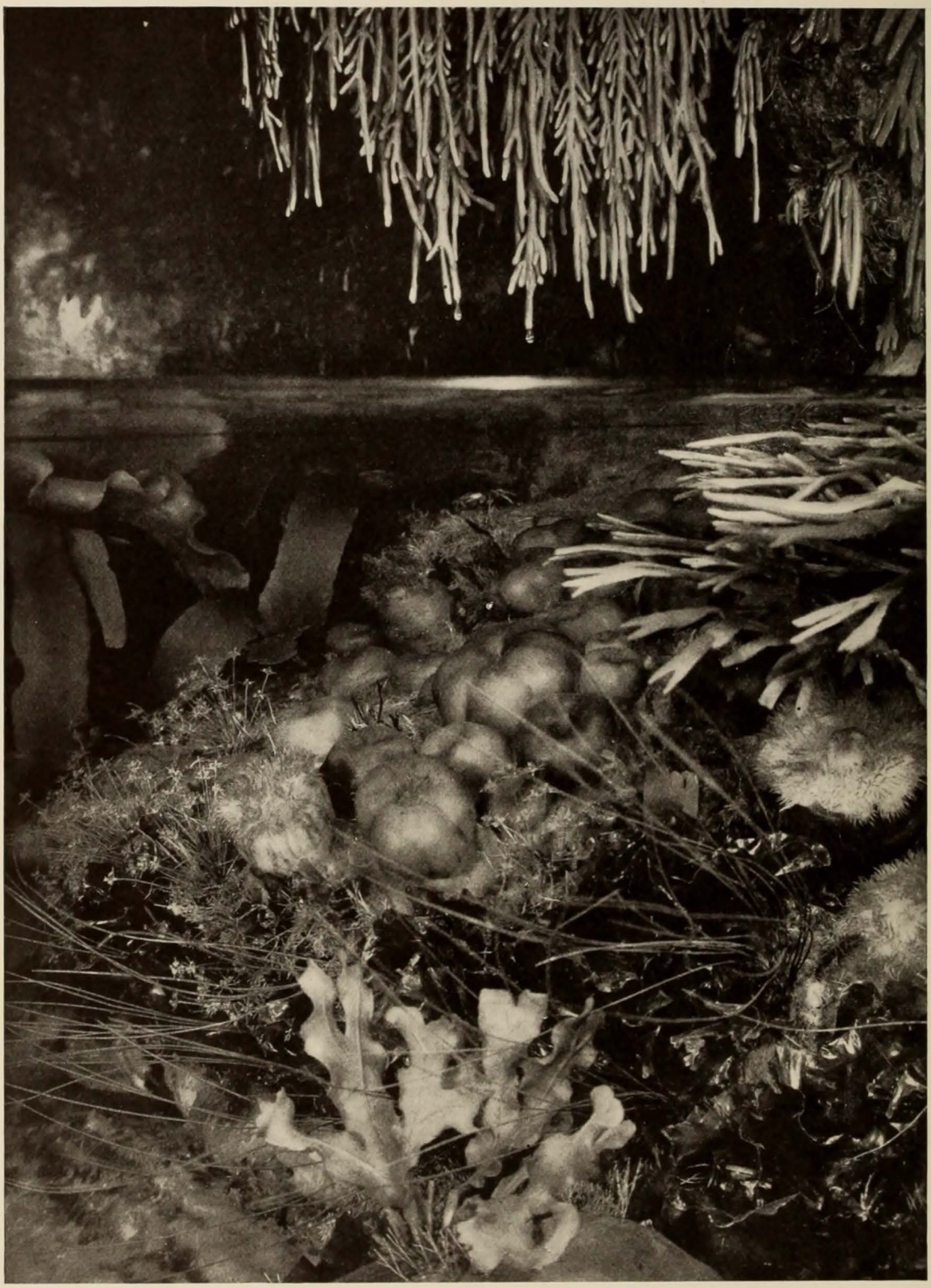
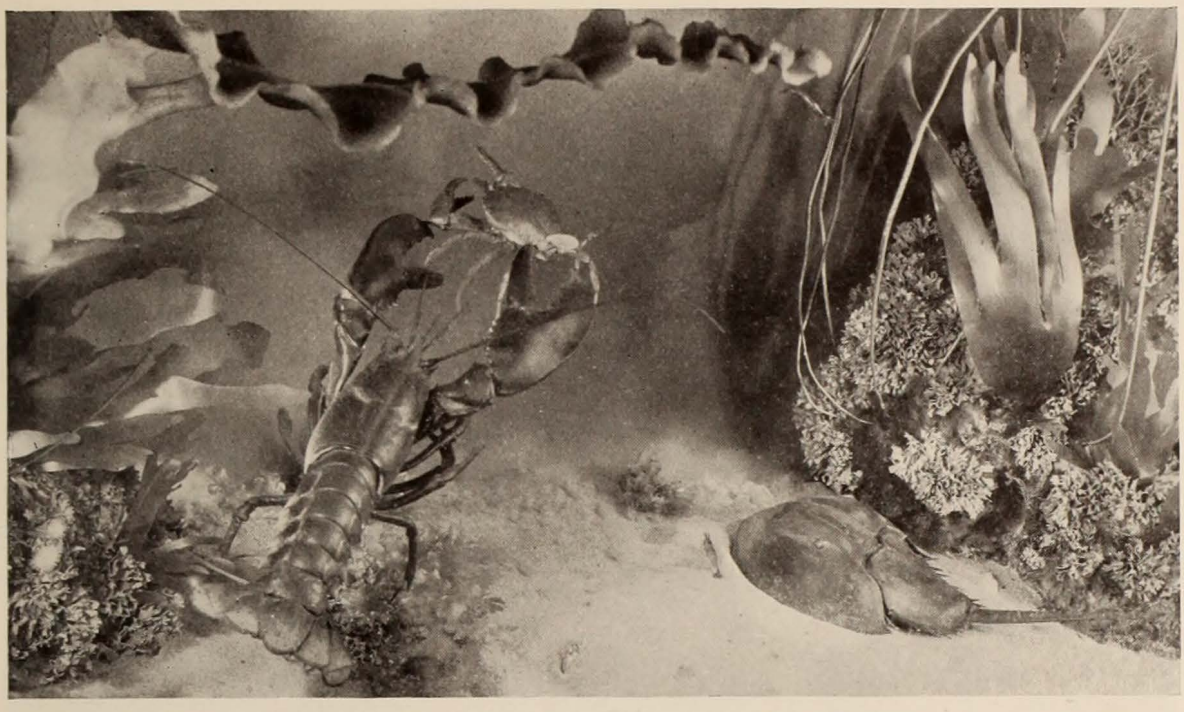


A PICTURESQUE CORNER OF A TIDE POOL

A colony of sea anemones (*Metridium marginatum*), is clustered together on a rocky shelf. At the right, one or two anemones, sheltered beneath the floating rockweed, have ventured to expand their fluffy circlets of tentacles. Though of flower-like beauty in color and form, they are nevertheless voracious creatures, armed not only with tentacles but also with sting cells, with which they slay and capture small creatures, and even fishes which form their food.

A number of the anemones have contracted, withdrawing mounth and tentacles within their bodies



ANIMALS OF A SUBMERGED SANDY SEA FLOOR

OUTPOSTS OF THE SEA

The Animals of the Tidal Realm—Marine Hosts that Today Assail Our Continental Borders, Endeavoring to Repeat the Conquest Attained Ages Ago by the Ancestors of the Present Land-animals

By ROY WALDO MINER
Curator of Marine Life, American Museum of Natural History

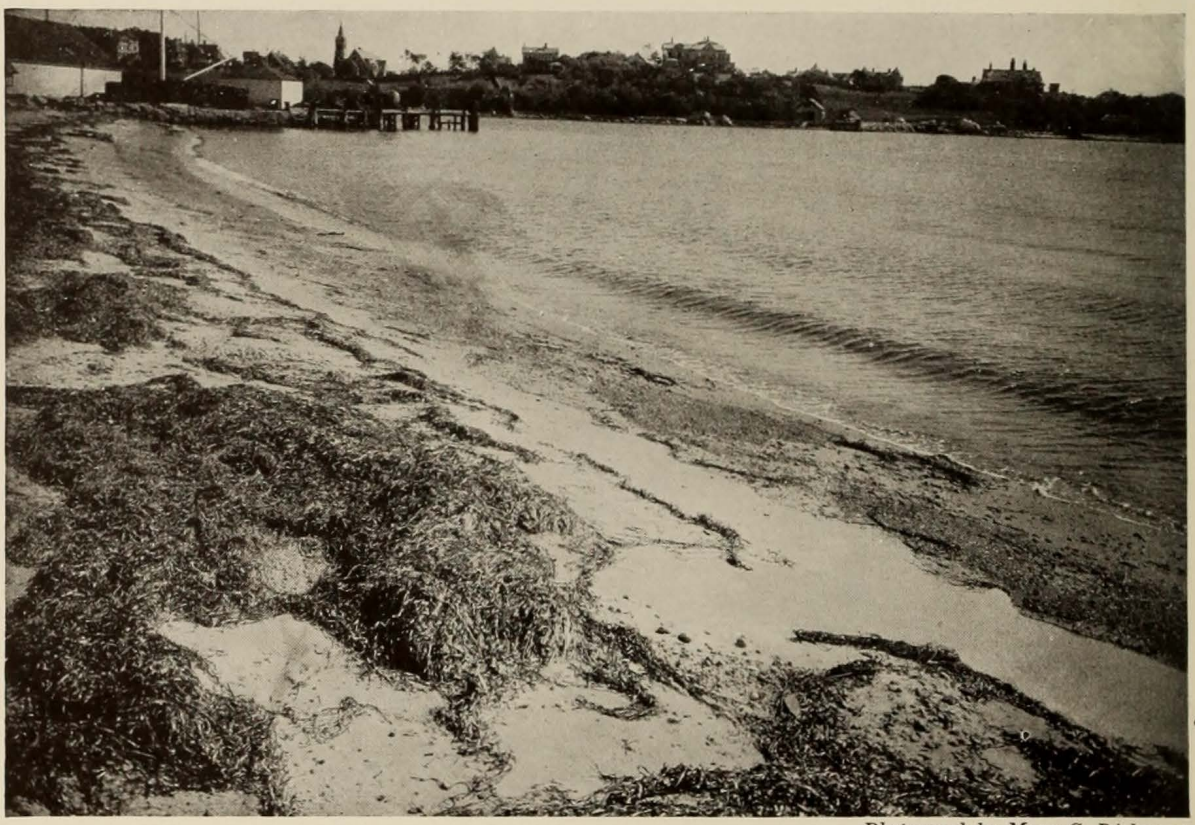
THE daily rise and fall of the tides along the seacoast alternately submerges and lays bare a strip of the shore which varies in width from place to place according to the local range of the tide.

Thus, the vertical rise of the tides off the New England coast south of Cape Cod is only from one to two feet. Within Cape Cod Bay and Massachusetts Bay, on the other hand, it rises nine to ten feet. This is also true along the Maine coast, where the tides are deflected to the northwest by the curvature of the shore, joining the incoming waters farther north. These, in turn, are finally compressed into the narrowing funnel of the Bay of Fundy with the result that huge tides of thirty to forty feet are created at its tip.

In Passamaquoddy Bay, New Brunswick, the rise is twenty-two feet, and this is the extent to which it covers the vertical cliff-walls of Bliss Island, at the entrance to the bay. St. Andrews Point, within the same bay, has a very gradual slope, and, at low water, is uncovered for two miles. Hence, the tidal zone varies greatly in area.

The nature of the substratum composing it also differs. It may be of rock in the form of vertical cliffs, as above mentioned, or sloping and, perhaps, broken into terraces. On the exposed shores it may consist of sand beaches, or mud flats in sheltered coves and bays. It may be covered by rocky bowlders, broken down from the cliffs by wave action, or eroded out from headlands of glacial drift by the washing away of the soil enclosing them.

The animal and plant life of the permanently submerged continental shelf has oveflowed into this stretch of semi-



Photograph by Mary C. Dickerson

A SAND BEACH AT LOW TIDE, WOODS HOLE, MASSACHUSETTS

Long lines of seaweed, thrown up by the waves, are arranged in ribbon-like bands, beneath which sand hoppers and beach fleas are concealed

terrestrial, semi-marine territory. The continental shelf is the submarine continuation of the tidal zone seaward. It slopes gradually to about one hundred fathoms, beyond which the bottom falls more rapidly to the greater depths of the ocean. This outer face of the shelf is known as the continental slope, and varies in its abruptness from a clifflike drop to a gradually accelerated gradient continuing the surface of the shelf itself. The width of the continental shelf also varies considerably. It is extremely wide in the North Atlantic, from the American side around to the British Isles, but quite narrow off Spain and Portugal and the western coast of Africa.

It is believed that the comparatively shallow waters of the continental shelf and slope witnessed the great evolution of marine life. Here it became diversified and abundant, for here the conditions of life are at their best. From this region marine creatures were crowded out into the deeper oceanic waters, on the one hand, or specialized for the pressures and darkness of the deep abysses. On the other hand, they invaded the tidal zone, the fresh waters and, finally, the land. The evidence is strong that wherever and whenever life originated, the continental shelf is the region of its greatest evolution and the center of its radiation. The very fact that its location has shifted during geologic ages, as the continental areas were thrust upward or were worn down again through erosion, until the continental shelf invaded their lower reaches as epi-continental seas, has caused the living creatures inhabiting the shallow waters to be subjected to varying conditions and an intense struggle for existence, resulting in the preservation of adaptive changes and the elimination of those that were nonadaptive. As we see it now, the tidal zone and its inhabitants

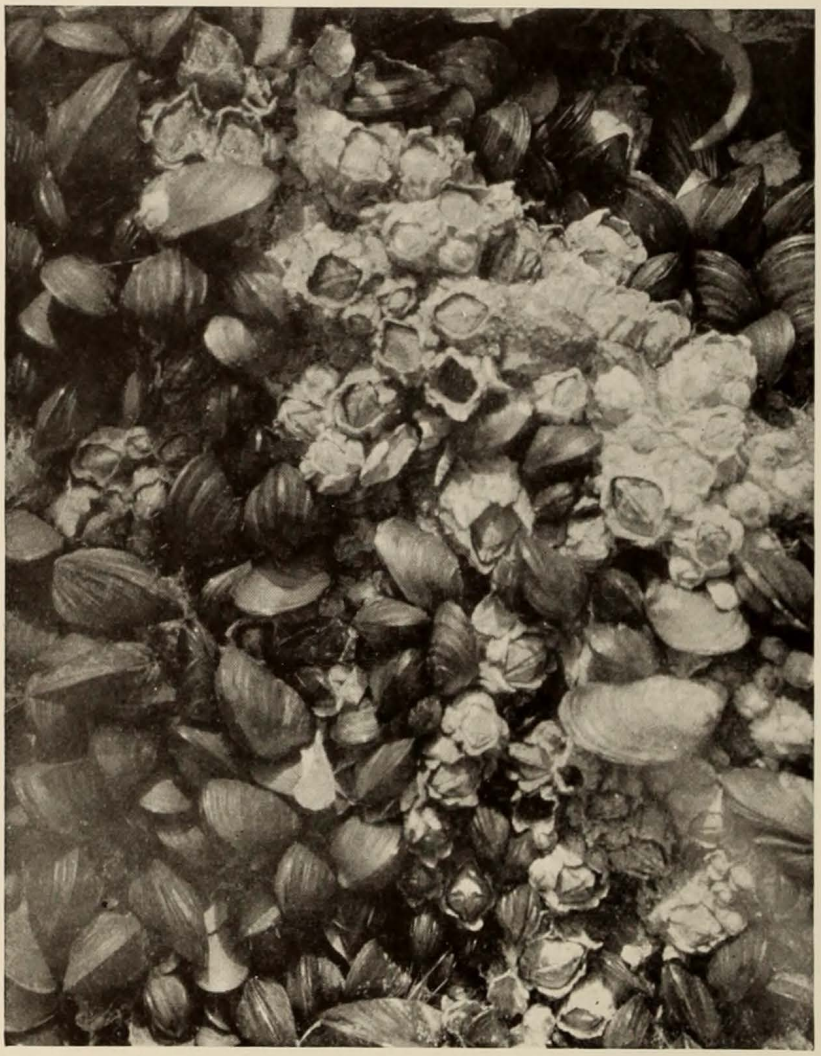
represent a present-day phase of that struggle, for here only those sea creatures can exist that are adapted to the strenuous daily changes of environment involved in being alternately exposed to the air and submerged by the tidal flow. It is so striking an example of the results of natural selection on a large scale, and so accessible to everyone, that the thinking visitor to the shore will have no difficulty in reading the chief lessons taught by the inhabitants of the tidal region.

In the first place, it must be remembered that the tidal zone is the pulsating border of the great life-association of the submerged continental shelf. Secondly, life is so abundant that animals and plants of all species not only live where conditions are appropriate and easy for them, but also struggle to live under adverse circumstances. Those that inhabit the totally submerged shallow seas find life comparatively easy, exposed as they are to the sunlight, yet covered by oceanic waters chemically harmonious with their body fluids—a fluid hydrosphere filled with food and replete with oxygen for the animals, and carbon dioxide for the plant life. Nevertheless, many also struggle to live under the more trying conditions of the tidal zone, where they maintain their position in proportion to their hardiness and their capacity to withstand exposure.

Everyone who walks along the shore at low tide is familiar with the zonal or banded distribution of the animal and plant forms. This is especially conspicuous on the rocky shores of New England, north of Cape Cod. The white band of rock barnacles (*Balanus bala-*

THE CLIFFS AT NAHANT, MASSACHUSETTS, AT LOW TIDE

The tidal zone is clearly marked on the vertical rocky face, as a band nine feet in width, showing the white frieze of barnacles above the stratum of seed mussels and rockweed which extends to the water line. A rock tide-pool, overarched by a weed-festooned natural bridge, is shown in the foreground. This locality is reproduced in the American Museum as the "Tide-Pool Group"



A CROWDED COLONY OF MUSSELS AND BARNACLES

Both mussels and barnacles can withstand long exposure to the air by enclosing enough sea water within their shells to keep their breathing organs moist. Together with the periwinkles (*Littorina litorea*) and "purple" snails (*Thais lapillus*), they invade the upper regions of the tidal zone. The snails, especially, suggest a transitional stage toward terrestrial life

noides) is displayed at the summit of the zone, their close-set marble wigwams crowding each other to form a snowy frieze. Ambitious periwinkles (*Littorina litorea*) swarm here and there, climbing slowly but surely upward over the housetops of the barnacle colony, and even mounting far up the bare rocks above it.

The barnacle frieze is overlapped below by the rockweeds (*Ascophyllum nodosum* and *Fucus vesiculosus*), their olive-brown fronds draped in graceful fringes down to the water's edge, disclosing beneath their parting masses the continuous embossed mosaic of the black edible mussel (*Mytilus edulis*), which encrusts the rock up to the lower limit of the barnacle zone. Bright patches of gaily colored and banded "purple" snails (*Thais lapillus*) may be seen grouped upon the mussel colony, which extends downward and below the water mark. Here it is succeeded in turn by another zone characterized by the green sea urchin, a small animal rejoicing in one of the longest scientific names known to zoölogy, *Strongylocentrotus droehbachiensis*.

The sea plants below the rockweed zone include the common pink coralline (*Corallina officinalis*), the Irish moss (*Chondrus crispus*), and the dulse (*Rhodymenia palmata*). These are laid bare only by the lowest tides, and even then are continuously washed by the surf. Also at this level the two species of the common sea star (*Asterias vulgaris* and *Asterias forbesi*) are to be found, the former varying in color through red, orange, purple, and blue, and distinguished by a white spot, the ambulacral plate, between two of its arms. The latter is usually greenish brown, with a bright orange ambulacral plate. Associated with them are the common sea anemone (*Metridium dianthus*) and two species of rock crab (*Cancer borealis* and *Cancer irroratus*).

This zonal arrangement depends upon two main factors, the exposure factor

and the food factor. It is obvious that the height above the low-water mark at which a sea animal can live depends upon its ability to withstand exposure to the air, for the upper limits of the tidal zone are, of course, left bare the longest. The periwinkle, in fact, is far on the way toward adaptation to terrestrial life. As the tide falls, it captures a few drops of water, which bathe its breathing organs and are kept from evaporation by a closely fitting horny plate closing the shell-opening. In this way it may remain many hours out of water. It is a vegetarian, feeding not only on the surface of rockweed, but also on minute algæ high on the rocks and among the barnacles.

The barnacles likewise are provided with means of retaining a few drops of moisture or moistened air beneath four little valvelike plates that close the top of their shells. They feed on the microscopic diatoms brought on the crest of the incoming tide. When they are submerged, each barnacle may be seen to unfold its quadripartite doors, whereupon the little plume of feathery feet waves to and fro, and, like a casting net, captures its tiny prey, which is immediately withdrawn within the closing gates. Agassiz has said that a barnacle is nothing but a shrimp standing on its head within a marble house, kicking its food into its mouth with its feet!

The mussels, occupying the zone immediately below the barnacles, can withstand exposure, but for a shorter time. They, too, feed upon diatoms. Both mussels and barnacles are preyed upon by the voracious "purple" snails, which also can withstand exposure at low tide, though many remain hidden under the moist drapings of rockweed.

The mussel zone is limited above by the barnacles, which tend to spread over the mussel shells and choke them by their more rapid growth, and below, by the zone of green sea urchins, which feed

COLLECTING IN THE TIDE POOL AT NAHANT, MASSACHUSETTS

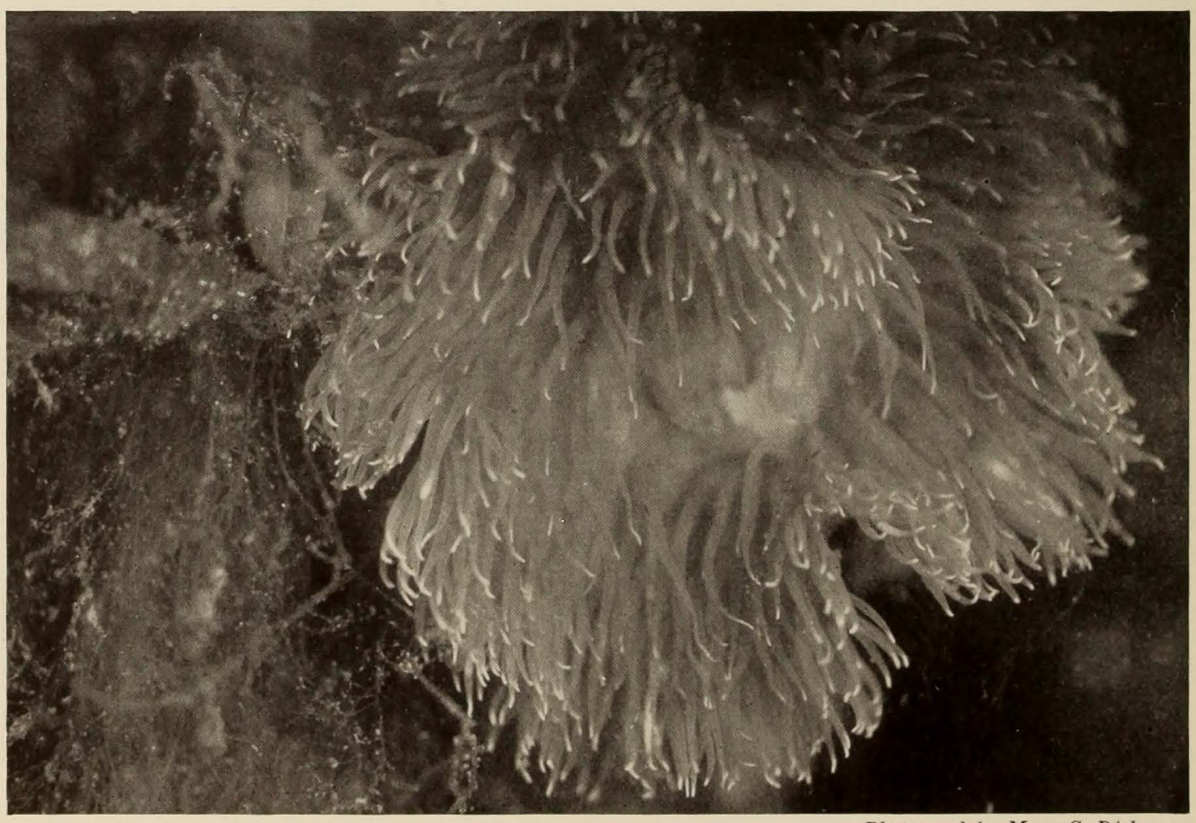
Basins and crevices in the rocks remain filled with water when the tide falls below their level, and thus harbor not only the life of their own zone, but also many creatures which ordinarily live below the low-tide mark

upon the mussels. The latter are also preyed upon by dog whelks (*Buccinum undatum* and *Lithodomus decemcostata*), two large snails found on our northern rocky shores. The whelks bore round holes into the mussel shells and suck out the animal.

Down near the low-water line voracious sea stars envelop the mussels with their arms, attaching their tube feet to the opposing valves, which they pull apart by gaining a purchase with their arm tips on the surrounding substratum. Then each sea star protrudes its saclike stomach from the central mouth on the underside of its body, and inserting it between the valves of the mussel, pours out its digestive fluid. Thus, it digests the poor creature within its own shells, while it absorbs the fluid products of digestion through its stomach walls. Sea stars devour oysters even more voraciously, and are the most hated enemies of the oyster fisherman.

On terraced and sloping rocky shores there are many crevices and basins that are left filled with water at low tide. These occur at various levels and, in the lower part of the tidal zone, are especially rich in concentrated animal and plant life appropriate to the level at which they occur, and also to all the zones below that level. At flood tide they are invaded by the eggs and larvæ of many creatures usually found only below the low-water mark, which are able to live and develop in the pools because these are always filled with water. Thus the pools become veritable sea gardens of great beauty and fertility.

Here gay-colored sea stars occur in great abundance, hiding in crevices between bowlders covered with velvety brown Irish moss glimmering with iri-



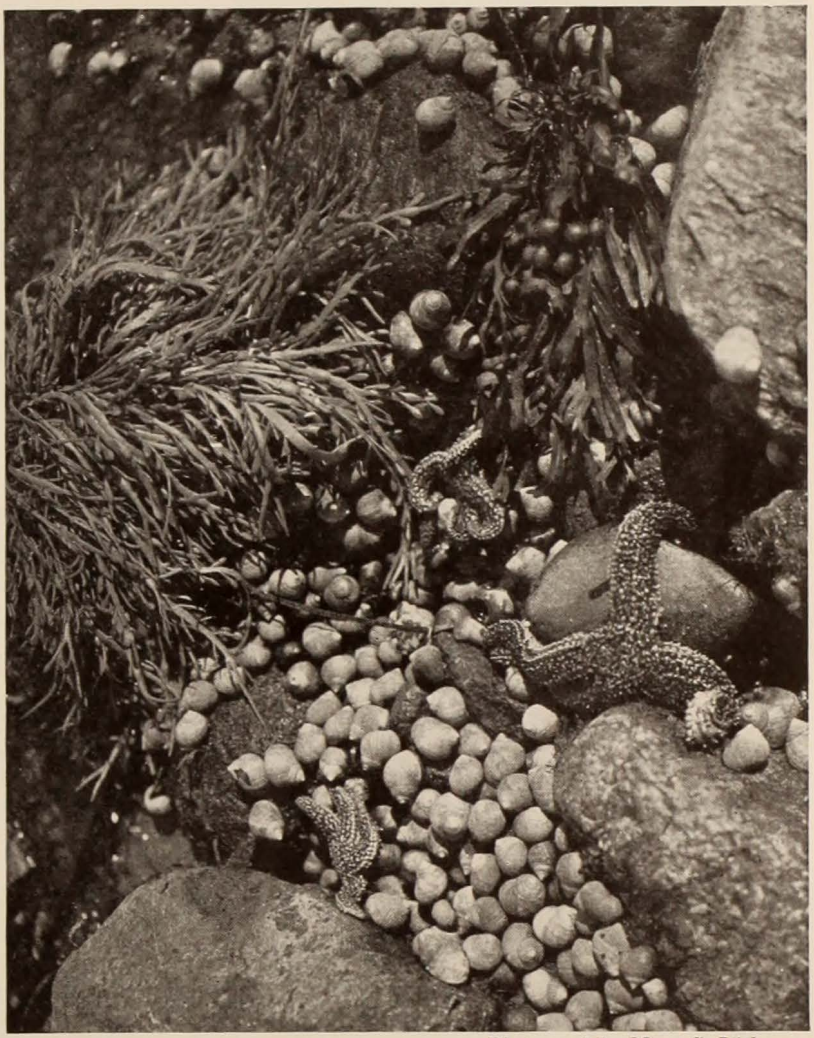
Photograph by Mary C. Dickerson

A SEA ANEMONE WITH BEAUTIFULLY EXPANDED TENTACLES

These flower-like animals (*Metridium dianthus*) live at or below the low-water mark, often in great numbers. Their petal-like circlets of tentacles are armed with sting cells and surround a central mouth. Free-swimming creatures, including small fishes, are caught, stung to death, and devoured. The anemones vary widely in color, from brown through pink, cream, white, and deep orange

descent violet tips and overhung with clustered chimneys of the gray-green crumb-of-bread sponge (*Halichondria panicea*). Feathery, ruby-hearted hydroids (*Tubularia crocea*) fringe a shelf occupied by sea anemones with their rich stock-in-trade of color, ranging from brown, mottled with white, through plain white to rich pink and deep orange.

Two green crabs (*Carcinides mænas*) are sparring with each other in a corner beneath the ruffled overhanging fronds of the brown kelp (*Laminaria agardhii*). The entire rock surface, lining the pool, is gay with sea mosses or encrusted with red-purple and brown calcareous algæ. Thus the pool is replete with life, refreshed and renewed by the periodic incoming tides with their floods of food and oxygen.



Photograph by Mary C. Dickerson

PERIWINKLES AND SEA STARS EXPOSED AT LOW WATER

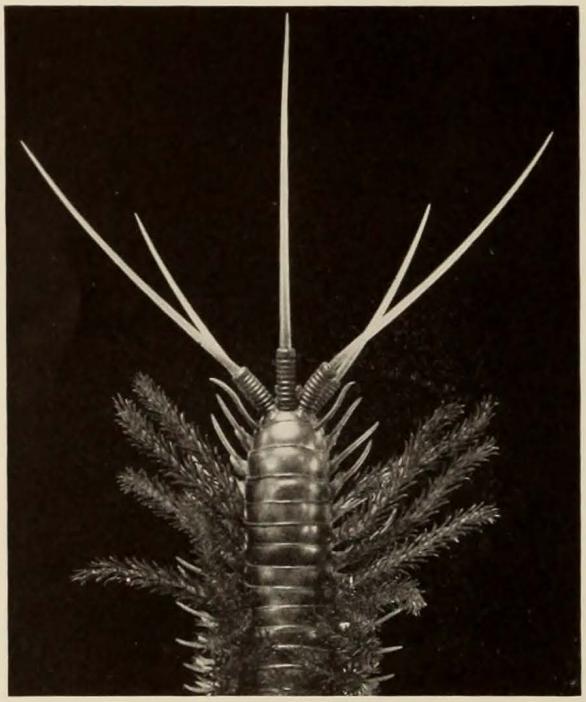
The ubiquitous periwinkles are abundant near the low-water mark, as well as in the upper reaches of the tidal zone. The sea stars, on the other hand, can withstand exposure for only a short time, and are therefore confined to the lower part of the tidal zone and the waters below the low-tide mark

While the northern New England shore is characterized by its rock-bound coasts, sandy beaches occur here and there, hemmed in by granite headlands, and mud flats are found in sheltered locations. But southern New England is typically low and sandy, beginning with the great sand spit which is Cape Cod. This forms a barrier hindering, to a degree, the intermingling of northern and southern forms.

Animals of the rocky coasts and regions of high tides must be adapted for clinging to crevices and for withstanding the battering of the waves and the rush of tidal currents. Animals of sandy and muddy regions, on the other hand, tend to be of burrowing habits, while the surface-living creatures are scavengers.

A sand beach, at low tide, appears to be a particularly barren place. Yet the close observer will detect signs of life. For example, he may chance upon little heaps of sand here and there, which betray the presence of the sand-collar snail (*Natica duplicata*).

If one waits till the tide begins to rise and covers these burrows, a stirring of the sand may be seen, and soon the snail will issue forth and crawl slowly over the



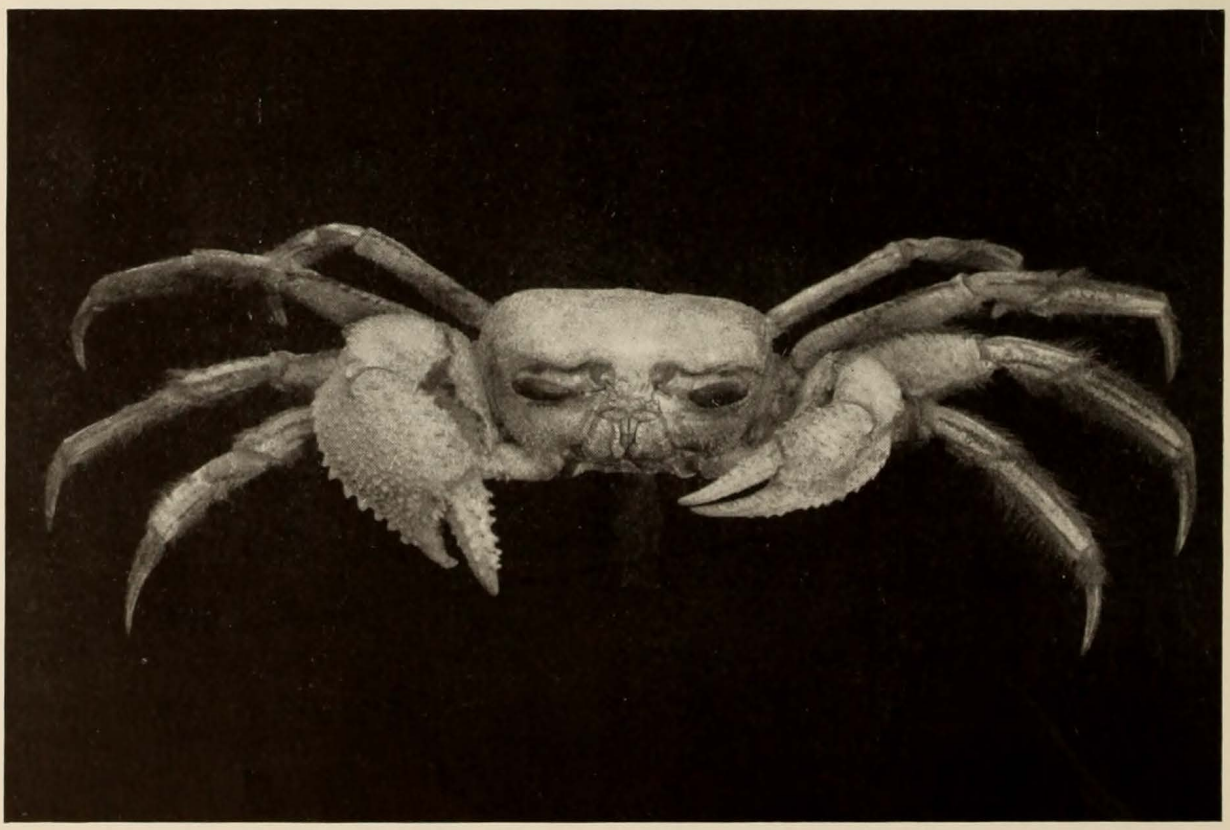
THE PLUMED WORM

This martial looking knight (*Diopatra cupræa*), of the sea bottom, lives in a chimney-like den, the upper portion of which projects into the water above the ocean floor

sea bottom. As it unfolds its foot and expands its "apron," it seems impossible that so huge a creature could have been packed into a spherical shell the size of a tennis ball. Above the apron it waves a pair of tapering tentacles, furnished with eyespots near the base.

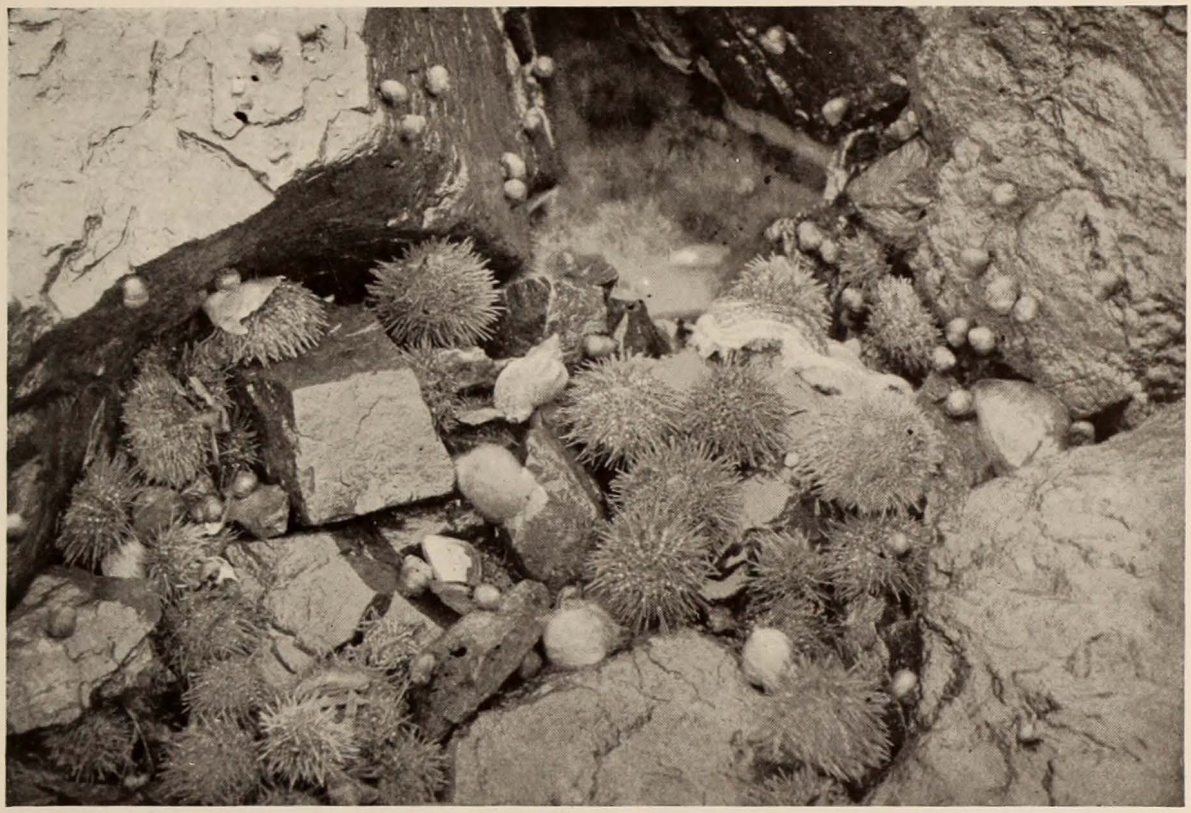
The egg-case of this snail is a flat, nearly circular, collar-shaped structure, to which the sand adheres. The underside is completely lined with transparent, beadlike eggs. These sand collars are often picked up on the beach in a dry condition, when they crumble at a touch.

Other burrowing animals of the sand beach are the razor-shell clam (*Ensis directus*), so called from its elongate bivalve shell suggesting the handle of an old-fashioned razor; the lady crab (*Ovalipes ocellatus*), a swimming crab with hind legs terminating in oval paddles and a carapace beautifuly marked with



A FLEET-FOOTED INHABITANT OF SAND BEACHES

The ghost crab (*Ocypoda albicans*) is aptly termed, for its light, sandy markings so closely resemble the color of the beach, that it flits like a shadow along the shore and seems actually to disappear from the sight of the observer when it comes to rest



Photograph by Mary C. Dickerson

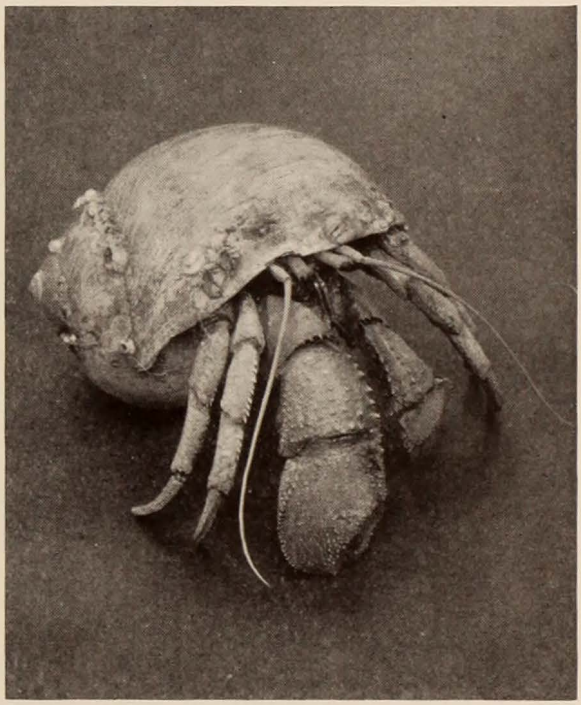
A COLONY OF GREEN SEA URCHINS

These sea urchins (*Strongylocentrotus droehbachiensis*) are abundant at or below the low-water mark on our northern rocky coasts. They feed upon the edible mussels (*Mytilus edulis*) and both, in turn, become the prey of the voracious sea stars (*Asterias vulgaris* and *forbesi*)

small purplish spots; and the ghost crab (*Ocypoda albicans*), found on sandy beaches from Long Island southward. This crab makes its burrows above the low-water mark and its whitish carapace so closely imitates the sand that it is difficult to see it, except when in motion. It runs with great speed, and, when it stops, seems to disappear.

Mud flats are especially rich in sea life. Everyone is familiar with the great stretches of edible mussels (*Mytilus edulis*) that are found on certain mud flats between the tides, and the kind of sandy mud in which one digs for clams, whether the soft clam (*Mya arenaria*), or the "hard shell" (*Venus mercenaria*).

But let us take a water glass (which is just a bucket with a glass bottom), and wade at low tide in a sheltered cove near the edge of a patch of eelgrass. Where the shallow sea floor is composed



A MEMBER OF THE STREET-CLEANING FORCE OF SHALLOW WATERS

The hermit crab (*Pagurus pollicaris*) is one of the scavengers of submerged, muddy sea bottoms

SEA STAR DEVOURING OYSTERS

The sea star mounts the shells of the living oyster with its five arms partly enfolding the two valves of its victim. It then applies its hundreds of tube-feet to the outer surface of the shells by means of small terminal suckers. With the tips of its arms it braces itself against the surrounding objects and exerts a strong, steady pull, that gradually forces the oyster shells apart

of sandy mud, let us place the water glass on the surface and look through it. A busy scene at the edge of a miniature submarine forest composed of the eel-grass roots, is disclosed to our eyes. Tiny hermit crabs (*Pagurus longicarpus*) are scuttling to and fro. Soon they gather about a bit of decaying substance and immediately begin to pull it apart. Mud snails (*Nassa obsoleta*), attracted by the tumult, crawl up from various quarters, leaving a little groovelike track in the mud behind them. A larger hermit (*Pagurus pollicaris*) lumbers along and scatters the smaller fry as he pulls the decaying morsel to pieces. Small, transparent shrimp (*Palæmonetes vulgaris*) dart in to get their share.

The hermits, the shrimp, and the mud snails are the scavengers of shallow water —the street-cleaning department of the submerged mud flat—and they are thorough in their work. It is true that the hermits acquire their uniforms by theft, for they appropriate the shells of sea snails. Sometimes they find them empty and ready for use. At other times, they are said to eat out the former occupant first, thus obtaining a meal and a home simultaneously. When they grow too large for the shell they happen to have, they hunt for another, and it is amusing to see them make the change. They leave the old shell and, quickly settling into the new one, try it a few seconds, then change back to the old home. After a short interval the new shell is tried again, and the process is repeated several times. In the end, the hermit may walk off with the old shell after all!

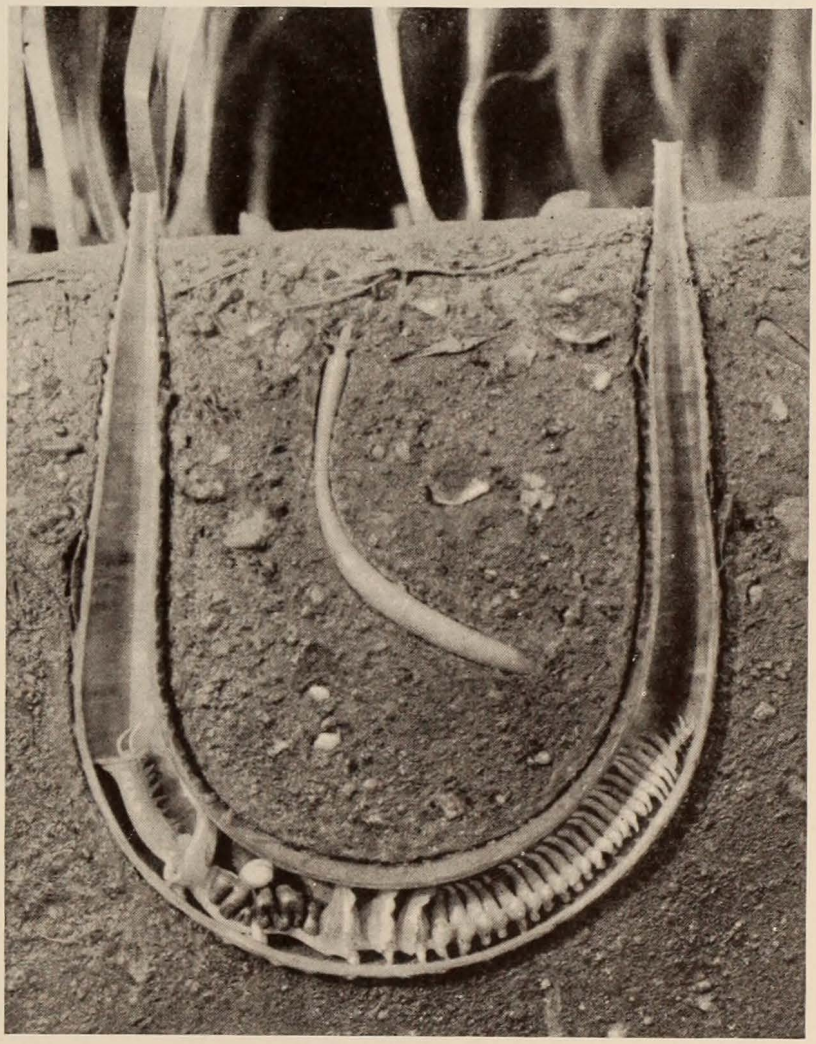
We now direct our gaze at the shallow

sea floor in the clear space between the eelgrass and the shore. Here on the sandy mud we begin to see certain details that hitherto have escaped our attention. Clusters of broken shell and bits of seaweed, apparently caught together by the currents, now resolve themselves into neatly cemented chimneys leading to some underground abode, for gently waving filaments projecting from the summit betray the existence of an occupant.

We carefully dig down into the sea bottom around the structure and remove a long, tapering, parchment-like tube, with the thickened chimney of shell-fragments at the top. After washing it, we cut it open in a glass dish of sea water, and out floats a beautiful, struggling creature, clad in segmented steel-blue armor, and bearing several sets of blood-red plumes upon its shoulders, while five tapering, lancelike palps are flourished in front. This knight of the submarine castle is the plumed worm (*Diopatra cupræa*).

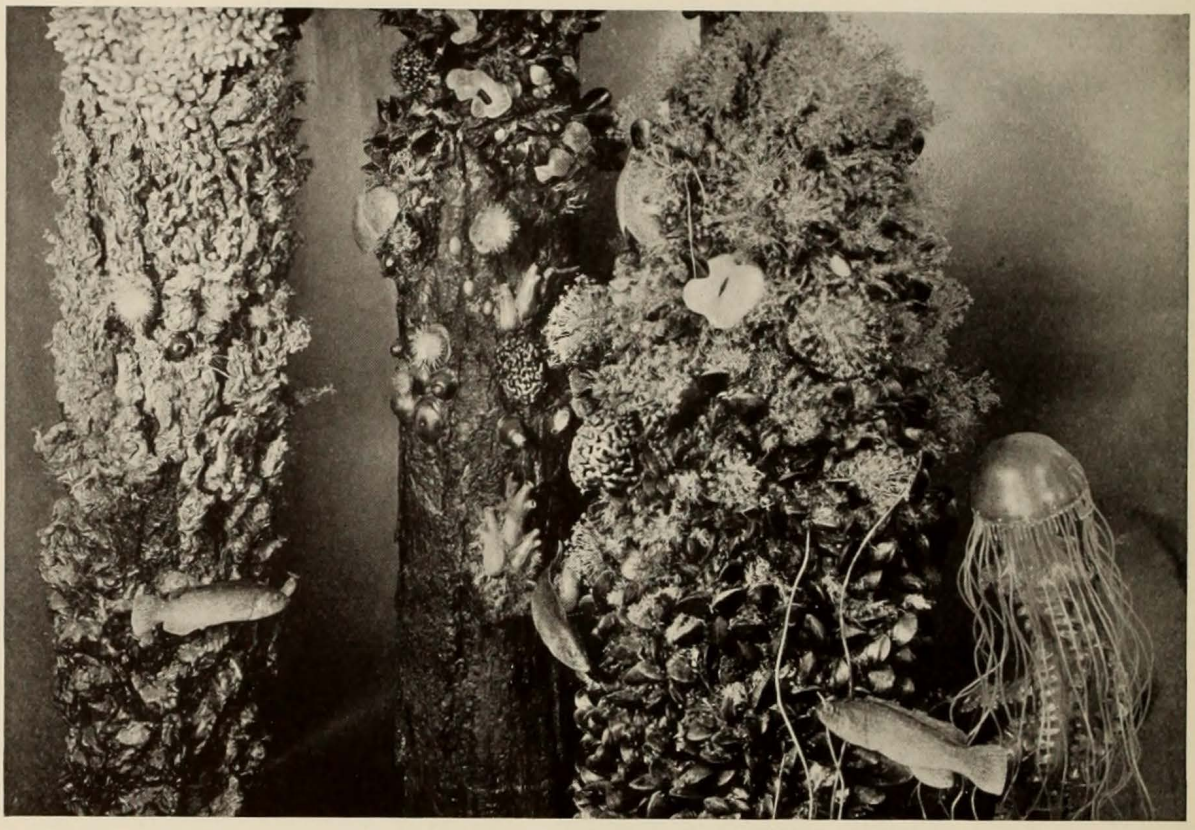
Likewise, paired chimneys of smoother texture a little nearer the shore cause us to dig up a U-shaped tube, also of parchment, belonging to the parchment worm (*Chætopterus variopedatus*). This is the most curious worm of all. It is a strange creature with a flat, shovel-like head, armed with bunches of golden bristles, behind which is a pair of long arms having grooves lined with moving cilia. Then comes a pulsating cup, attached to the upper side of the body, followed by three disc-shaped segments, and last of all is the tapering tail, disclosing through its transparent walls an internal structure brightly colored green, yellow, and pink.

The parchment worm lives in the bottom of its tube, the three disc-shaped segments fitting the cavity neatly. As



A BUILDER OF SUBWAYS BENEATH THE SEA

The parchment worm constructs for itself a U-shaped tube formed of a gluelike secretion from glands in its own body, which hardens into a parchment-like substance upon contact with the sea water. The strange looking architect lives in the bottom of his home, the two chimneys of which project into the sea. By means of three disclike segments in the middle part of its body, which just fit the interior of the tube, the creature pumps a stream of water into one chimney and out through the other, from which it abstracts the microscopic creatures that form its food



ANIMALS OF THE WHARF PILES

The piles of old wharves along our shores are completely covered with a great diversity of animal forms, all of which are adapted to filtering out the microscopic food from the sea water in which they are submerged

the worm contracts its body rhythmically, these segments move like the pistons of a suction pump, drawing a stream of water into one chimney, passing it through the tube, over the body of the worm, and out the other chimney. The microscopic food contained in the sea water is filtered out by the combined action of the arms and moving cup, and transported through a trough lined with moving hairs up the mid-line of the body to the mouth of the worm.

It is obvious that not only the sea bottom, but the soil beneath the sea as well, is alive with myriads of creatures, adapted by their structure for breathing and obtaining their food in this particular habitat. Likewise, if we examine the wharf piles of an old wharf, we shall find it clothed completely with sea grapes, tube-building worms of brilliant, flower-like hues, feathery hydroids, scarlet sponges, mussels, sea anemones, members of every animal phylum, all adapted to a stationary form of existence, equipped with various contrivances for extracting minute creatures for food from the life-giving sea in which they are bathed.

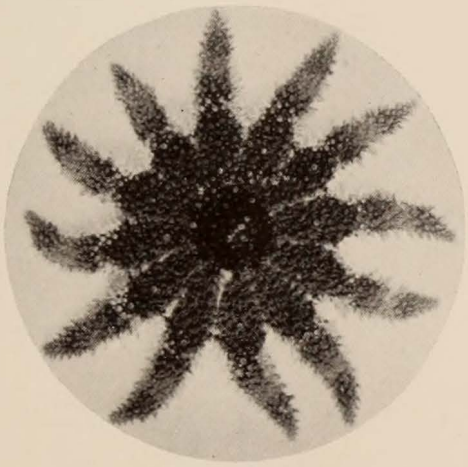
Life pulsates wherever we search along the borders of the sea. Living creatures endeavor to occupy every kind of habitat, and, if it is favorable, swarm through it so vigorously that all the space is occupied and many are crowded to the limits where marine life is precarious.

The pressure to escape to an air-breathing existence drives certain species to the limit of the tidal zone, so that we see, at the present time, compromises between the marine and terrestrial form of life, as in the case of the periwinkles and purples among mollusks. These are closely related to other snails (*Ampullaria* and *Siphonaria*) which have both water-

breathing branchiæ and air-breathing lung, and finally the snails, *Cerithidea* and *Cyclophorus,* terminate the series with a complete air-breathing apparatus. The same pressure now continues which, in the Carboniferous Age, forced the conquest of the air by the lowly progenitors of the land vertebrates.

The comparative anatomy of marine invertebrates shows us that there has been a gradual closing of the body cavity and circulatory system in higher marine animals, thus segregating the body-fluid which bathes their tissues and is closely similar in composition to the salt solution that we call sea water. It is very significant that the inorganic salts of the blood of terrestrial animals are the same as those found in the ocean.

Thus the water of the seas, closely adapted in its composition for the life requirements of the lowest marine creatures and circulating freely through their cavities, has been succeeded by a fluid closed off from the outside within the bodies of higher organisms, some of which finally shook themselves free of their ancestral abode and emerged into the upper air. It is almost as if the invaders of the land carried a portion of their original habitat enclosed within them to bathe their tissues with the precious sea environment and so insure their continued existence in their new world.



THE SUN STAR OF OUR NORTHERN SHORES

This brilliant creature, (*Solaster papposus*), bright scarlet with white-banded arms, is one of the most conspicuous inhabitants of our rocky coasts

FOR THE PEOPLE

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