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Article XXIII.—MODERN LABORATORY METHODS IN VERTEBRATE PALÆONTOLOGY.

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Plates LII–LVII.

The brief description which I read before the society of Vertebrate Palæontologists at New Haven, Conn., in December, 1907, published in the 'American Naturalist' for January, 1908, under the title, 'Modern Methods of Excavating, Preparing and Mounting Fossil Skeletons,' was of necessity but a very sketchy outline owing to the time limit allowed each paper. Through the courtesy of Prof. H. F. Osborn, President of the American Museum of Natural History and Curator of the Department of Vertebrate Palæontology, under whose general direction the work of our laboratory is conducted, I am now enabled to present a more detailed description of the latest and most practical methods for general use in a vertebrate palæontological laboratory.

Primitive Laboratory Work.

As much as forty years ago Professors Marsh, Cope, and Leidy had prepared vertebrate fossils, in this country. This was done mainly with a view to description and identification, and the work was carried out in a rather crude manner. The bones were cut out of the matrix in the simplest way with poor tools, and as they came out in pieces they were cemented together with common carpenter's glue. This held them together only as long as the glue retained some moisture; they fell apart just as soon as the glue became dry. This, however, may not have been the case in every palæontological work-shop but certainly it was so in most of the American ones.

During later years much experimental work has been done in connection with field and laboratory methods, and my object in this paper is to explain in detail "the best results which we have yet been able to attain," and the present practice in the American Museum and other laboratories of Vertebrate Palæontology.

Field Work.

I have already stated in my preliminary paper that it was not my intention to give any instructions in reference to collecting fossil bones in the field, for the reason that I have not myself done much along this line. However, having been engaged as preparator for the past thirty-two years — sixteen years with the late Professor Marsh at New Haven, Conn., and over sixteen years in my present position under Professor Osborn — I take this opportunity of demonstrating from practical experience what method of treatment and preservation in the field I have found most practical and reliable for giving the best results in the museum laboratory.

In the early day of fossil collecting in this country, some fifty years ago, the bones were simply taken up, as Professor Marsh termed it, "in potato fashion," that is to say, the fossils were dug out of the ground where they were discovered in the same rough manner that potatoes are dug in the field. They were picked up in pieces, done up as far as possible in parcels in the order in which they had been taken up, and then left to the preparator in the laboratory to fit the fragments together again.

Joining the pieces together, however, was in a great many cases an utter impossibility, especially if the pieces were quite small and the fractures not characteristic enough to determine their position. This method fortunately has been gradually replaced by a better one, which is the result of the cumulative experience of a generation of fossil hunters; this is the method of "bandaging" the bones before taking them out of their place in the field. The collectors for Professors Marsh, Cope and Osborn, including the late Mr. Hatcher (who to my knowledge was the inventor of the "bandage" method), Mr. O. A. Peterson, Dr. J. L. Wortman, and later Mr. Barnum Brown, Mr. Walter Granger, Dr. W. D. Matthew, Mr. Albert Thomson and others, used muslin or burlap which is soaked in raw flour paste and applied to the bones in the field. (Any kind of coarse, loose-woven cloth, old burlap, bags or sacks which have been used for grain or potatoes, are easily obtained everywhere and are excellent for the purpose.) The cloth is well soaked in the paste and applied to the bones in the same manner as to wall paper. When dry this paste holds the fragments together so that the specimens can be packed and shipped securely.

The muslin should in nearly all cases be applied close to the bones and if great strength is required, as in the case of very large bones, burlap may be pasted over this. Even greater strength than this can be obtained by the use of plaster of paris instead of flour. The "bundle" may even be reinforced by the use of iron rods or strips of wood, whichever may be obtainable.

Whenever plaster is used to hold larger blocks together it is generally desirable to have a thin layer of paper (tissue or parafine paper preferred), between the bones and the plaster, to avoid the binding of the plaster to the specimen.

Paper should also be applied to the cloth when a plaster jacket over the cloth becomes necessary, as this saves a great deal of labor in the laboratory in freeing the bones from the bindings. The paper is applied by first moistening the surface of the bone with gum water or shellac, then laying on the paper and pasting it down with a wet brush. When flour paste is used it is

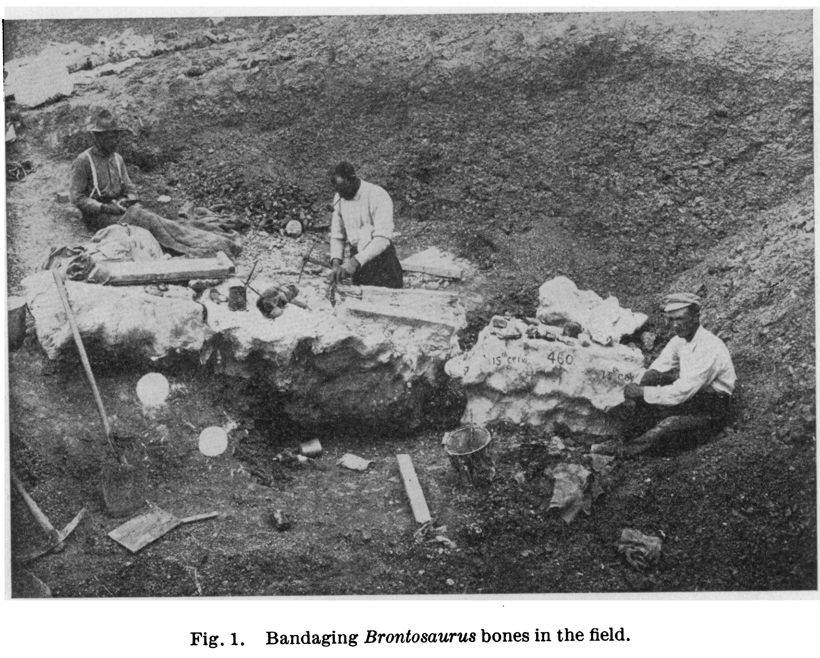

Fig. 1. Bandaging *Brontosaurus* bones in the field.

nearly always desirable to introduce a small quantity, of a solution of corrosive sublimate, say a half grain to a quart of paste. This keeps the paste from fermenting, and poisons the latter so that the mice will not eat the bandage. A few words may be added in regard to the treatment of the bones before lifting them from the ground.

As stated in my previous brief paper it was customary in earlier days to use a thin solution of gum arabic for soaking the softer and more porous bones in order to harden them for packing and transportation. This was practical for very porous and soft bones but the gum did not penetrate deep enough into hard and less porous bones, so that they remained rather crumbly inside. Gum when dry becomes very brittle and by absorbing the dampness of the atmosphere freely loses its binding power.

Through the experimenting of the various collectors of the museums in America, it has been found that shellac is in nearly all cases superior to gum. It is absolutely waterproof and penetrates much more readily into the soft and partially decomposed bones than gum; and when sufficiently dry, makes the bones far more resistant. Denatured alcohol is most generally available, but wood or grain alcohol penetrates a little better and dries faster. To prevent discoloring of the bones, white shellac should be used for light colored bones, while common brown shellac is preferable for dark bones, as it dissolves much more easily than white shellac.

Some European collectors use hot glue water for hardening the bones and matrix. This penetrates well and hardens well but has the disadvantage of softening up in damp weather and makes the preparing and restoring in the laboratory much more difficult, since glue acts as a retarder to plaster.

No standard rules, however, can be prescribed as to the manner of treating different bones. This must be left entirely to the judgment and experience of the collector. A good collector's work always meets with the sympathy of the preparator, while on the other hand the work of a poor and careless collector creates ill feeling between the latter and the preparator, not to speak of the damage done to specimens and the valuable time expended in the work of preparation.

In closing this subject I should also like to mention that it is a great fault on the part of some fossil collectors to free the bones too much from the matrix, for this weakens the specimens and makes them more difficult to transport. Unless the matrix is very soft and loose, as, for instance, sand, loose clay, etc., sufficient matrix should be left on the bones to insure safe transportation, and it always pays to ship a few extra pounds of rock, which can be easily removed in the laboratory, as this preserves the specimens intact.

When large blocks containing dislocated skeletons had to be taken in sections I always found that if the collector had made a careful diagram, on which the respective sections were marked and numbered, it would be of great help to the preparator and of immense scientific value to be able to place the parts as they were found. I have found in my experience that some collectors do not pay attention enough to the packing and the labeling of the different parcels. This is one of the most important parts of collecting and should never be neglected.

It is always a pleasure for the preparator to handle specimens well preserved and carefully labeled in the field, and the time saved in preparing and piecing together such specimens pays well for the careful treatment and labeling by the collector.[1]

I have said more about field work than I intended to say, but while the skilled and experienced collector needs no advice, yet such advice may be of much use to the inexperienced beginner.

Laboratory Work.

Unpacking.— The unpacking of bones containing palæontological specimens should be done systematically. To pack a box well, the specimens should be placed in such a way that enough space is allowed for sufficient packing material, straw, hay, excelsior, to be put between the single specimens or parcels, so that rough handling in transportation cannot injure the contents.

A well packed box or case should be unpacked carefully by removing the cover as easily as possible and then removing first the packing which holds the packages in place, so that the parts may be taken out freely. It is of great importance to look over the labels and keep the parcels or parts of bones as much as possible together in trays. If one parcel contains several other small ones in which the smaller bones or parts of bones are wrapped up singly, as is often the case in taking up feet, ribs and parts of skulls, it is always advisable to keep the contents of each little package separate, but to keep the associated packages together in a larger tray. This method is time-saving later on in piecing the broken bones together. The most important thing in packing is to save the field labels. A good collector always labels his specimens with date and locality on every main parcel or bundle. It is the duty of the preparator to save these labels, that is to remove them

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[1] A valuable suggestion has been made by Dr. W. D. Matthew, which I desire to quote: "Collectors should keep in mind that the expense and time of preparation usually far exceeds the entire cost of collecting specimens in the field. In the experience of the larger museums, a great part of the collections sent in year by year is stored away unprepared and useless for study or museum purposes and with little prospect of its ever becoming available. The more choice, more complete, or better preserved specimens are naturally taken up first. The rest of the collection goes into storage and too often remains there indefinitely. Collectors therefore who desire to see their collections prepared, studied, and placed on exhibition promptly, would do well to send in only the best and most easily prepared of the specimens they discover to use every possible means to decrease the necessary time and expense of laboratory preparation and to avoid wasting time and effort in collecting poorly preserved specimens or those which are not of first class scientific interest or exhibition value."

However, this only applies if the collector is a man of sufficient scientific attainment to be able to judge of the scientific value of a specimen on the spot; for, as every palæontologist knows, it is sometimes a mere fragment, or some poorly preserved specimen which is of inestimable value from the scientific point of view, and it would be unfortunate to reject such material in the field for more showy though much more common specimens.

If the collector is ever in doubt about a poor looking specimen whether it has enough scientific value to be sent, the safest rule, in my opinion, is to take it along.

from the specimen if pasted on, before preparing, or cut them out of the wrappers and keep them for reference.

The unpacked bones, matrix blocks, etc., should never be crowded too much in trays, so that they are allowed to knock against each other; this will surely injure delicate specimens. Carefully unpacked and well-labeled specimens can safely be handled and when stored should be easily accessible.

Preparing of Bones.— The preparation of bones consists of:

1. Removal of the matrix, sandstone, clay-rock, etc. This is done with a variety of special tools, to be described later.

2. Piecing and cementing the shattered and broken bones together and strengthening them so that they can be handled or mounted. For this purpose a variety of cements are used and the bone is soaked with thin solutions to strengthen it.

3. Repairing and restoring missing parts of bones. All preparation of fossil bones is delicate work and requires the utmost care, and in most cases skill also.

Freeing the bones from the bandage.— All bandages, especially those applied to the surface of the bones, should be removed very carefully by slowly wetting the paste with a sponge, allowing the bandage to become soft enough to be pliable. In pulling the cloth loose from the bones, care should be taken that loose fragments on the surface or other small pieces do not drop out of place. I find it usually advisable to replace the loose fragments at once so as not to lose them. Well preserved bones and those that are hard enough to handle, may be taken loose from the bandage and the pieces cemented together, but in the case of badly broken and weather-cracked specimens, such as crumbly bones, it is desirable to remove the bandage of one side first; then after the bone is soaked with shellac (if such is necessary) and the loose pieces fastened and the fractures filled in with plaster, a plaster bed should be made on the exposed side and the specimen turned over, to be manipulated similarly on the other side. Wherever a plaster layer or bed is needed to turn over a specimen of any kind, a thin layer of paraffine paper or a coat of lard oil should be applied to the surface of the bone to prevent the plaster from sticking fast.

Cutting the Bones out of the Matrix.— Well preserved and hard bones can be freed from the matrix with comparative ease, as they will stand the jar and blow of a hammer and chisel without injury, but a soft and crumbly bone, on the other hand, requires much care and patience, especially if the bone is imbedded in more or less hard rock. By frequently applying a solution of shellac or gum to the bones as the surface becomes exposed, it will toughen and harden the specimen, if time to dry is given, so that a very soft and crumbly bone becomes strong enough to be handled safely. I have

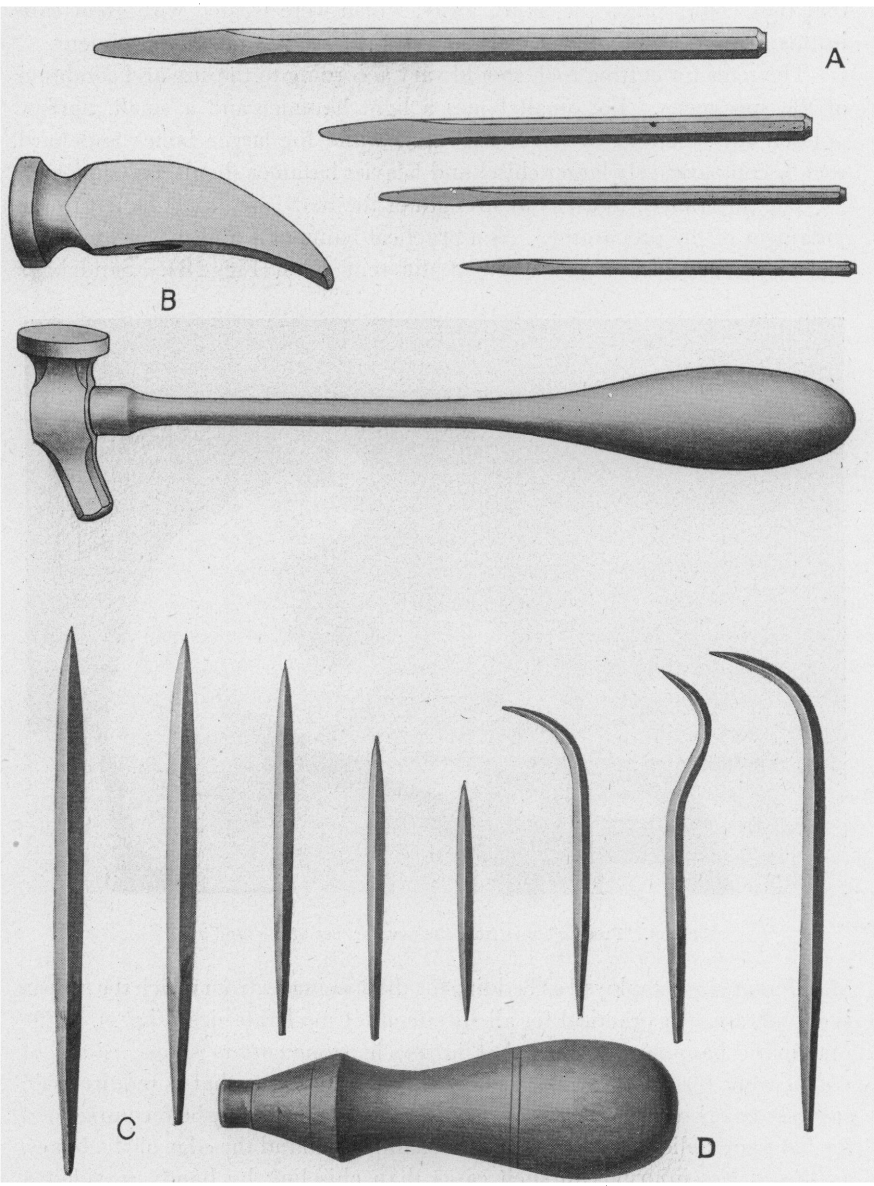

Fig. 2. A, B, chisels and hammer; C, D, awls, used in removing matrix. A little over one half natural size.

seen in the American Museum bones of great scientific value so crumbly that they could almost be blown away, which were treated with great care in this manner and looked almost as well preserved as perfect specimens.

The tools for cutting rock should vary according to the size and condition of the specimens. For small bones a light hammer and a small, narrow pointed chisel should be used (Fig. 2A), while for larger bones and hard rock a comparatively larger chisel and heavier hammer should be employed.

The selection of tools, as to strength of the blow, etc., must be left to the judgment of the preparator. As a practical hammer I find the shoemaker's hammer, which can be obtained of different sizes (Fig. 2B). Sand bags

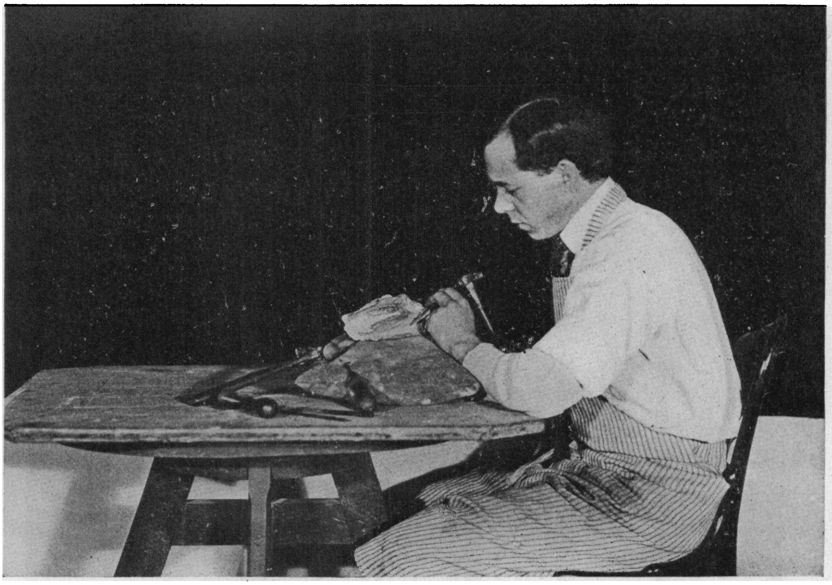

Fig. 3. Freeing bones from the matrix; use of the sand bag.

of different sizes employed as bedding for the specimens from which the matrix is cut off, are very practical for all specimens of moderate size (Fig. 3). The pneumatic hammer, such as that in use in stone cutters shops, is not of much value for heavy cutting, since the large hammer that is required can scarcely be operated with sufficient care, but the system may be recommended for light and delicate chiseling, as, for example, around the edge of the bones, as this is less injurious in such cases than chiseling by hand, provided a very light hammer is employed.

When larger, thin, flat bones are cut out of hard rock, such as scapulæ, pelves or parts of skulls, care must be taken that the specimens are solidly embedded on one side, while the matrix is being chipped off on the other, so as to prevent shattering; and a plaster bed should always be applied, if necessary, to prevent the bones coming apart. The delicate edges and the thin walls of the bones should be freed from the rock with great care. Whenever the bones can be traced under the rock, I have found it advisable to use as large a hammer and chisel as possible, to cut the large mass of rock off rapidly, but on approaching the bones greater care must be exercised, and the size of the chisel and hammer must be reduced so as to avoid all injury to the bones.

In my experience I find the so-called "crooked awl" (Fig. 2, C, D) made from the harnessmakers' or saddlers' awl, which can be obtained in all sizes at any harness maker supply store, a most practical and convenient tool, for removing from specimens all kinds of matrix of not too hard a character. This awl can be bent to suitable shapes and tempered and sharpened for hard and soft matrix, and is an indispensable tool for all palæontological field and laboratory work. As far as I know it was introduced by Prof. Marsh over thirty years ago and is now used in most palæontological workshops. After being heated to a cherry red and dipped in water the temper should be drawn over the curve a dark straw color, almost bluish, so as not to break off.

I may mention another tool which I find of great service, namely, the plumber's shave hook (Fig. 4, A). This, as well as the curved awl, serves as a scraper in scratching off soft matrix paste or plaster from the specimens, and both are also very useful in plaster work.

Many years ago we introduced into our laboratory the dental lathe with two sizes of flexible arms attached (Fig. 5). This little lathe of about $\frac{1}{8}$ horse power can be attached to any incandescent lamp block. Small size (up to 6 in. diameter) carborundum wheels can be used for grinding hard rock off the specimens; and with the flexible arm attached, which holds the smaller wheels also, it enables the preparator to grind hard rock off the specimens where a chisel could not be used with safety. Small rotary brushes (wire or bristle) may be attached for cleaning out cavities in the bones which otherwise could not be reached with ordinary tools. It also carries a drill chuck large enough to bore a $\frac{1}{4}$ inch hole in iron or bone.

For very light and delicate work, such as cleaning small specimens, teeth and small skulls and all fragile bones we have used with the smaller flexible arm the regular dental burrs such as are used by dentists, which enables us to remove not too hard rock from very delicate bones and teeth without injury to the specimens.

The regular dental engine is also employed in our laboratory for these purposes. This method is rather slow but is the one least dangerous to the specimens, and I can recommend it for all extremely delicate work.

We have also employed the "dental mallet" for very delicate chiseling. This instrument is an electric plugger such as dentists use in filling teeth. We had a large size constructed especially for our purpose which works well on all small specimens. The only disadvantage is that the mallet gets

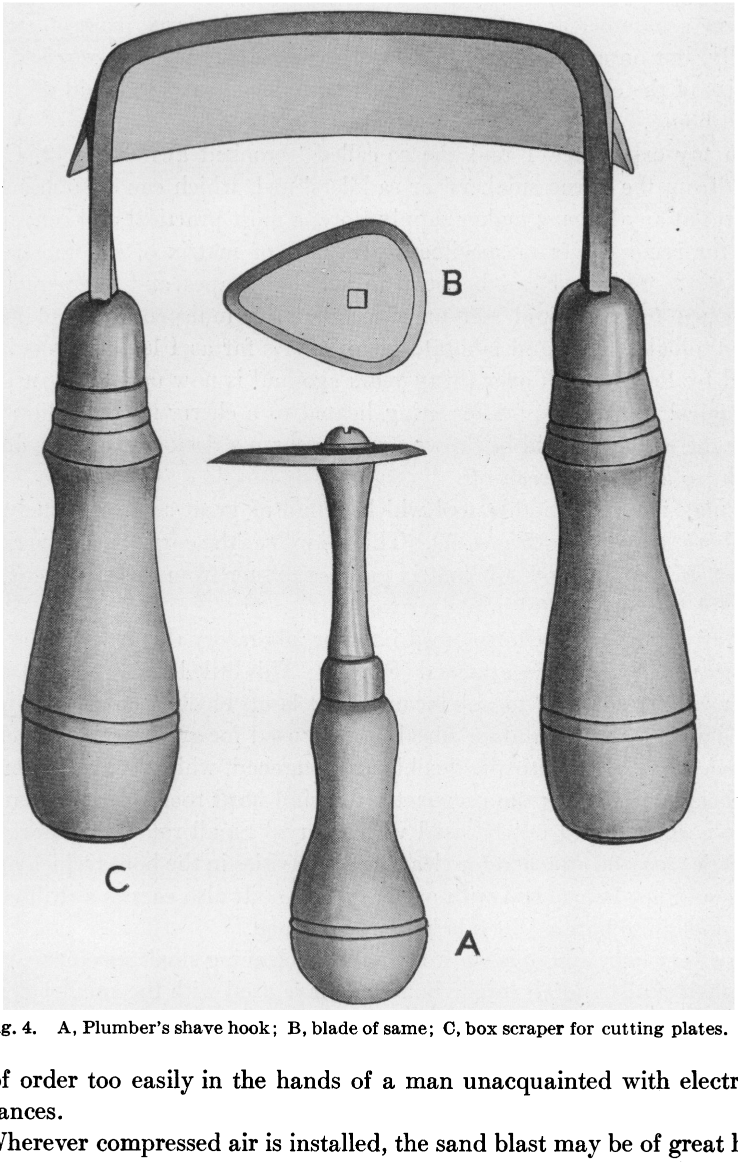

Fig. 4. A, Plumber's shave hook; B, blade of same; C, box scraper for cutting plates.

out of order too easily in the hands of a man unacquainted with electrical appliances.

Wherever compressed air is installed, the sand blast may be of great help in freeing the bones from their matrix. On very hard matrix however it produces but little effect. It can only be applied to specimens where the bone is considerably harder than the matrix.

We have also employed chemicals for freeing fossils from matrix which was so hard that steel tools, such as chisels, awls, etc., were of little use. If the matrix contains lime in any form, hydrochloric acid will soften it and allow the chisel to take hold; on matrices of other composition caustic potash may be of some help. These chemicals, however, should be applied with great care as in many cases the fossil as well as the matrix is attacked.[1]

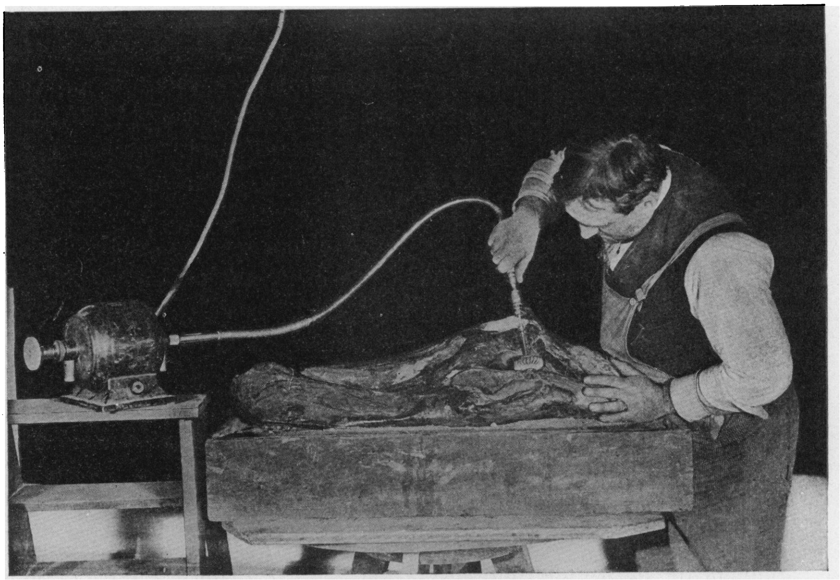

Fig. 5. Dental lathe, with brush on flexible arm.

[1] Dr. F. A. Bather of the British Museum of Natural History has published in the 'Museum Journal' for September, 1908, an article entitled "The Preparation and Preservation of Fossils," in which he discusses among other things the chemicals used in freeing fossils of all kinds from their matrix. I here quote his suggestions, which I consider of great value. After describing various methods Dr. Bather continues:

"In applying several of these methods I have received the greatest help from Mr. Walter F. Reid . . . . Chairman of the London Section of the Society of Chemical Industry. . . . Since the action of these differentiating solutions is slow and often uncertain, Mr. Reid has devised the following ingenious method, which may be applied to any fossil of which the matrix contains carbonate of lime, either as the main constituent or as a cement. Assuming that a small portion of the fossil is exposed, this is painted with a protective solution. For this purpose Mr. Reid has a special solution of cellulose in amyl or ethyl acetate made flexible by the addition of castor-oil (I cannot give the precise formula). Instead of this, one may use an alcoholic solution of 'Brillac,' which is a synthetised shellac of exceptional hardness quite recently placed on the market.

Piecing the Fragments Together.— The piecing of the broken bones is a very difficult problem and requires a great deal of patience as well as knowledge of the form of the bones. A preparator who loses patience easily and is of a nervous disposition will never make a good fragment piecer. Some preparators take a quantity of broken bones, lay them out on a table and begin by trying to fit every piece within reach to the piece held in the hand, in the same way as one would try to put together a "Chinese puzzle." This method is not conducive to the best results.

I will take this opportunity to illustrate the system that I learned from Prof. Marsh, more than thirty years ago. When fragments have been picked up lying loose, by the collector, that is, such fragments as have been isolated or washed away from their proper association, so that the remains of a number of bones have been mixed up together, it is always a good plan, to select those pieces that can be identified as belonging to a certain bone and keep them together; also those that show their near relation, by their shape, or characteristic fracture. Pieces from the edges of the bones, pieces of skulls, of vertebræ, of limb and foot bones, should be kept together in separate spaces or in shallow, pasteboard trays, so that if the preparator works on piecing a skull, he will not be wasting time in handling the pieces of vertebræ or even of limb bones.

Before beginning to put pieces together all fragments, if hard enough, should be washed clean so that the fractures can be seen distinctly. This is of great help in finding contacts.

Some of the most important specimens, some of them of immense value to science, have been pieced together from hundreds of fragments, the opera-

" A solution of pure shellac would no doubt serve if Brillac could not be obtained. The exposed portion of the fossil being thus coated with one or other of those solutions, the specimen is suspended in an acid called hypo-acetine. This partly dissolves and partly softens the matrix according to its greater or less calcareous constitution. After a period varying from half-an-hour to twenty-four hours, according to the nature of the matrix, the specimen is taken out, washed in pure water, and allowed to dry. The softened matrix is then removed with a brush of bristle or horse-hair. Any freshly exposed portions of the fossil are then coated with the protective solution and the whole suspended in the hypo-acetine. The process is repeated indefinitely until the whole of the matrix is dissolved and brushed away and the complete fossil exposed. The protecting collodion may then be removed by acetone or ether-alcohol.

" After being used for some time the hypo-acetine loses its power. One then adds to it a 'restoring solution,' which precipitates the limestone and restores its original virtue to the hypo-acetine. . . .

" It may, of course, be possible to use other acids such as hydrochloric or acetic, but the hypoacetine which is the result of considerable experiment, seems to have a more equable action. This process is particularly suitable in the case of bones, which being of phosphate of lime, are not so readily attacked by the acid as is the carbonate of lime in the matrix. I have, however, used it for fossils of pure calcite.

"Some matrices containing little or no carbonate of lime are not attacked by hypo-acetine or similar acids; such for instance are slates and the purer shales. These and other silicates, or even pure silica such as sandstone, require other treatment."

tion often taking days and weeks of patient and conscientious effort on the part of the preparator. It is always taken for granted in such cases that the collector has gathered all the pieces that could possibly be found.

Cementing Pieces Together.— The substance or cement used to fasten the fragments together is of various kinds and qualities. To my mind it is very important to know which is the best cement for a given kind of piecing. As mentioned at the beginning of this paper, in the early days ordinary carpenter's glue was used with poor results, later on I have myself used a mixture of carpenter's glue and plaster, which held a little better, if applied properly but this had the disadvantage of becoming soft and rotten in a damp place.

A preparation, which the late Mr. Jacob Geismar introduced (as far as I know, a composition of carpenter's glue soaked in very little water and then cooked with linseed oil) was a pretty fair cement; but it did not have enough binding power, and was more or less subject to decomposition when too old.

There are also a number of cements mentioned in technical books, especially in those treating of the different binding properties of cements, etc. Some of these may be useful for different classes of work in a palæontological laboratory but their manufacture is so tedious and difficult that the material employed and time spent make it too expensive for use in large quantities.

There are different kinds of cement on the market used for cementing porcelain and crockery which we have used for years past in cementing together very small and hard bones such as teeth, little foot bones, etc., with the best result, but for large bones these cements are impractical not alone on account of being too expensive but also because it would take too long for the bones to become dry. Any kind of cement which takes much time and experience to mix, is impractical for a large "bone shop."

We have introduced in our laboratory a very simple and easily obtainable cement, which answers almost every purpose. This is a mixture of alabaster plaster with a solution of the best gum arabic, which makes a very powerful cement for fastening small as well as large pieces together. The gum is dissolved in hot water (one pound of gum to 3¼ quarts of water) mixed well with the plaster to a thick cream, and applied to both fractures, which must be absolutely clean and free of any greasy substance. Done in the proper manner, this cement holds the fractures firm and I can show bones here which were cemented with this composition at least fifteen years ago and which now if handled roughly would break in a new place, but not in the line of joining.

Another good cement for hard bones where the fractures are smooth can be made by mixing prepared glue or so called fish glue with fine plaster.

The glue should be thinned down somewhat with water say to about half its strength and mixed thoroughly with plaster to a thick cream-like consistency; if enough plaster is mixed in this makes a very powerful cement much stronger than gum and plaster; but it does not hold very well in damp places since it absorbs moisture very freely. In dry rooms on the other hand it will last very well.

The plaster cement should be mixed afresh every time a small number of breaks is to be mended and applied to the broken surfaces, which are then pressed tightly together and the bone set up in a tray of loose sand, or on a piece of modeler's clay until the cement is well set. To mix cement in small

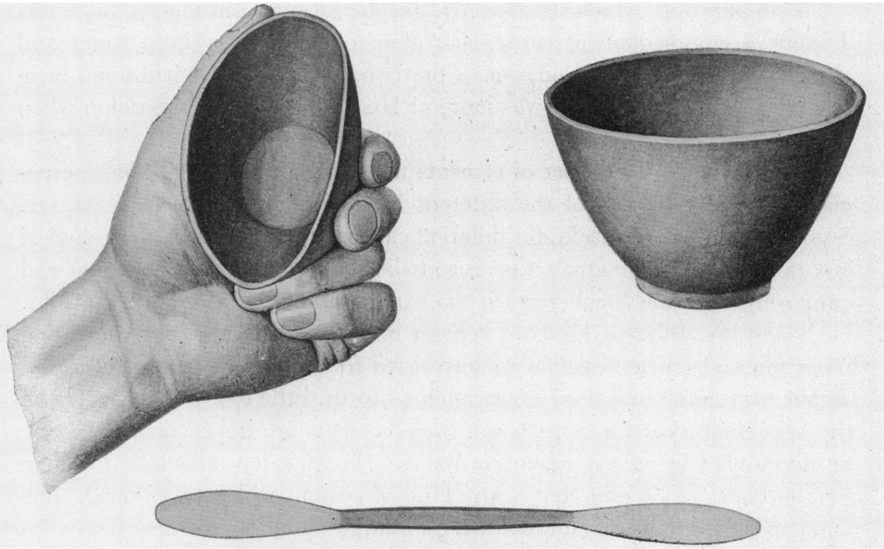

Fig. 6. Rubber cup and spatula.

quantities I find the rubber cup, such as that used by dentists, very practical, since it can be cleaned so easily by squeezing the cup when the plaster has set which allows the hard plaster left to drop out (Fig. 6). It depends largely on the skill and conscientiousness of the preparator whether the bones hold together or fall apart when touched. When a bone can be bored with a steel drill which is the case with a great many bones, an iron rod or wire should be inserted and imbedded in plaster to hold the parts together.

Restoring the Bones.— The restoring of missing parts of bones requires a great deal of skill and not every preparator becomes perfect in this line of work.

To my mind it is necessary in the case of a good many poorly preserved bones to restore the missing parts, in order to preserve what there is, as, by frequent handling, the fractured parts will crumble away until nothing remains. When larger parts of a bone have to be reproduced, it is important to have the restored part attached properly to the bone part so as not to become loose; therefore wherever possible, holes should be bored and wires inserted in the bones on which the plaster can get its hold; and wire netting of the proper size or other wires should be fashioned to the shape of the part to be restored and imbedded in the plaster. This will make a much stronger restoration and if it becomes cracked it will not fall apart.

In restoring work I find modeler's clay ("plastiline") a great help in building up walls to hold up the soft plaster or for rough molds to hold the plaster until it becomes set. For all restorations we almost exclusively mix the alabaster plaster with a solution of yellow dextrine, about one pound pulverized dextrine to three quarts of water. Dextrine dissolves very readily in boiling water. This mixture has about the color of light coffee and when mixed with plaster of the consistency of thick cream, sets very slowly (in about fifteen to twenty minutes), a fact which is of importance in building up the restored parts.

In former years we used mostly gum arabic for restoring as well as for fastening pieces together, but we found that the plaster mixed with gum is much more brittle than that mixed with dextrine, as the latter contains some sort of a starchy substance, which makes the plaster decidedly tougher than that mixed with gum. I have also used dextrine in fastening pieces together although it has not the binding power that gum has, and I would not therefore recommend it for this purpose.

In order to make the plaster set more slowly than dextrine-mixed plaster ordinarily would, a few drop of a very thin solution of gluewater (made of liquid glue) added to a pint of water, will keep the mixture from setting for over twenty minutes. Plaster mixed with gum sets almost as fast as plaster mixed with pure water, and if necessary to keep it from setting for ten or fifteen or twenty minutes, as may be the case in piecing bones, a little larger dose of glue water may be added as with dextrine, but too much glue lessens the strength of the plaster and all plaster should be allowed to set within thirty minutes.

Gum-arabic and dextrine in solution both help in hardening and toughening the restorations and it is advisable in all cases when the restoration is dry, to soak the plaster parts in the same solution employed in mixing the plaster.[1]

[1] Mr. F. A. Lucas, Curator of the Museum of the Brooklyn Institute of Science and Art, recommends mixing with the dry plaster althea (marshmallow) root in pulverized form, and he reports very good success as to strength and toughness of the plaster. I have given this a fair trial and after some experimenting I find that althea is in some respects equivalent to dextrine, with the exception that it retards the setting of the plaster somewhat less.

Coloring of the Plaster.— For coloring plaster mineral colors are preferable, such as yellow ochre, raw and burnt sienna, raw and burnt umber, earth green, and drop or bone black, the last not a mineral color. All these colors must be ground as fine as possible, and mixed in powder form with the dry plaster. To produce a bluish color in plaster black may be used; for a chocolate color raw and burnt umber and black; to produce gray I generally use black, yellow and a small quantity of raw umber and very little green; black and brown mixed with plaster give a blackish color. All variations in color can be obtained with the above mentioned colors, after a little experimenting.

It should be mentioned that all colors especially brown and black, when mixed with plaster in larger quantities either dry or in solution, weaken the mixture to some extent, and therefore in all cases, where much coloring matter is used, the solution used for mixing the plaster whether gum or dextrine must be proportionately stronger. Too strong a solution, however, makes the plaster crack, and this is the case with either gum or dextrine.

If the coloring material becomes lumpy, which is often the case, it should be pressed through a fine hair sieve, before mixing with the plaster, to prevent the mixture looking streaky when set. In repeating the mixing of colored plaster for the same specimen, which becomes necessary in restoring bones or in making large plaster mountings the mixture should be always of the same consistency (say of a thick cream) to avoid different shades in the plaster when set and dry, as otherwise the shades will vary, even if the same solutions and the same plaster is used.

Any preparator will soon become familiar with the above method after some experimenting.

Mr. Lucas has taken the formula from the 'Scientific American' and I reproduce it here.

"For retarding the setting of plaster, an addition of four to eight per cent. of althea (marshmallow) root powder produces a plaster that sets very slowly. The dry plaster is mixed with the pulverized root and the whole kneaded with forty per cent. of water to a paste. In consequence of the large proportion of pectine contained in the marshmallow root (fifty per cent.) we obtain a mass resembling a rich clay, which does not set until after an hour, and is then so hard and tough that it can be filled, turned and bored, and which can be employed for many purposes besides plaster casting. In a mixture of gypsum with eight per cent. of powdered marshmallow root, the setting is protected for a much longer period and the toughness of the mass increased. It can be spread, with the aid of a beetle on glass surfaces in large, thin sheets, which will not break when dry, are easily detached from the glass and by simple rubbing acquire a high polish. Where ochres and other coloring substances have been incorporated with the mass, it can be made, by proper kneading, to produce very fine imitations of marble. It can also be tinted after drying, with colors dissolved in water and afterwards made waterproof by soaking in linseed oil, varnish and lacquering or polishing. The locksmith can greatly increase its hardness, by mixing with it his iron filings, the picture-frame maker will never have any occasion to fear the cracking of his wares; according to its fineness and purity the gypsum will require a slight percentage more or less of water, which makes it impossible to define the exact quantity to be used. For many purposes it is nct necessary that the marshmallow root powder be of the finest quality."

Casting Bones, Etc.

Casting is a trade of its own and must be learned like any other. I do not wish to go into details about it; in a general way, however, a short account of the methods of casting employed in a palæontological workshop may be of interest, and I take this opportunity to discuss a few of the most customary processes.

In the American Museum a great deal of casting is done especially in the line of reproducing unique specimens, such as foot bones, skulls of rare forms and to a great extent also in the casting of restorations or models. I may mention that these casts are mainly made for the purpose of exchange with other natural history museums for study and a catalogue of such reproductions is issued by the museum.

The casting in our laboratory is done in various ways depending upon the character and form of the object to be cast. In making moulds for feet, especially for those mounted on plaster pedestals, also for skulls of all sizes, and for other light and delicate bones, we use the gelatine mould.

The gelatine I refer to for this work is a composition of the best French white glue soaked in water and thinned down with glycerine. The more elastic the glue is when dry, the better for this purpose; if possible it should be in flakes. The composition should be mixed according to the objects cast. For light and delicate casting where a very flexible mould is required, more glycerine should be used since it increases the flexibility and at the same time keeps the mould from shrinking too much, which is the case with a mould composed of glue only, when kept in operation longer than two or three days.

Glue moistened just enough so that it may begin to boil and then gradually thinned down with glycerine to the proper consistency will make a very elastic composition, useful in making casts such as those of brain cases where it becomes necessary some times to pull out the cast through the foramen magnum. However, the less glycerine used in a mould the better will it preserve during the process of casting, for the glycerine tends to make the mould soft and less capable of standing heat from the cast than a solid glue mould. It is therefore better for all large moulds in which the gelatine part of the mould can be an inch thick, to use glue only, cooked with water very slowly to a consistency that will allow it to run freely. The less water used, the stronger the mould. In our laboratory we have turned out as many as thirty casts from one glue mould; but this is an exception and the number varies generally between fifteen and twenty.

It is impossible to teach how to cast through mere explanation. This process is only to be learned through practical work, although a few words may be said regarding the process of preparing the mould.

Moulding.—If large objects are being cast a composite of pieces and glue-mould may be practicable, that is to say, all more or less even and smooth parts of the specimen may be moulded in plaster, and the rougher and more uneven parts or those which would be difficult to free from the specimen should be moulded in gelatine and the whole should then be held together by a plaster shell. How to arrange the different parts of the mould, so that they can be lifted off individually, must be left to the operator.

A combination mould is readily adaptable for the casting of large skulls where the portions around the teeth and other delicate parts may be moulded in gelatine. This reduces the number of pieces in the mould very much.

The specimen to be cast should first be given a thin coat of shellac to prevent the oil or other substances penetrating into the bone. It may then be embedded in clay to half of its circumference, that is, if the mould is to consist of two pieces only; if composed of more than two pieces, as may be often the case, the imbedding of the specimen should be arranged in such a way, that the parts of the mould resting on the imbedding can be lifted off freely; this should be the case in plaster as well as in gelatine moulds.

In gelatine moulding more than three or four pieces to the mould are very seldom required (large skulls excepted), on account of the elasticity of the gelatine; however, the parts must be arranged in such a way that they can be held together firmly by the outer plaster shell. But this matter is soon learned after a little experience.

The preparator should always be able to judge the strength and thickness of the gelatine required for a certain piece of moulding, considering the flexibility required as of great importance.

It often happens that in order to get the gelatine mould out of a deep cavity, it becomes necessary to use a wedge shaped plaster block, applied to the deepest part of the cavity allowing a thin sheet of gelatine between the plaster and the surface of the specimen so that, in removing the block, the gelatine can be loosened freely.

The thickness of the gelatine can be ascertained by rolling out a sheet of soft potters'-clay to the thickness required, and applying it closely to the specimen. The latter should be first covered with a sheet of thin paper to prevent the clay from sticking to it.

Now the plaster jacket should be cast over the clay and when set, it should be lifted off, to allow the removal of the clay. The shell may then be put back in position and the space left by the clay, filled with gelatine (Fig. 7). One or more air holes must be left in the shell to allow the air to escape as the gelatine forces it out.

When the glue mould is cold enough, so that the shell may be removed, one or two coats of a fully saturated solution of alum should be applied to the surface of the gelatine mould. This makes the surface tough and gives it more resistance to the heat produced in casting. This application of alum may be repeated several times.

Plaster Moulds.— All large bones, such as limb and foot bones, for instance, of dinosaurs or large mammals, large vertebræ that have no thin walls or cavities and all bones with even surfaces, in which case the moulds

Fig. 7. Pouring gelatine into mould.

may be composed of a small number of pieces, should be moulded in plaster. This sort of moulding requires more time and skill, but when a large number of casts are to be taken, it pays for itself in the end, since an almost unlimited number of casts can be taken from such moulds.

The different parts of the plaster mould must be carefully arranged in such a way that each piece can be loosened easily from the specimen to be cast, and the parts should be cut and notched, so that they reinforce one another by interlocking, so as to stay in place when the specimen is taken out of the mould. The whole must be held together by the outer plaster shell, whenever one is necessary, so as to stand as one piece.

After the original is shellacked and imbedded in clay, as mentioned above, a coat of lard-oil or a mixture of stearine and kerosene oil, or some thinner oily substance (as the case may be with the smaller bones) should be applied to the specimens, and care should be taken that the pores of the bones are filled with the shellac, so as not to allow the oil to soak into the bones; sufficient covering of oil must be allowed on the surface of the specimen, as otherwise the mould will become fastened to the bone. Each individual plaster piece should be taken separately when sufficiently set, and a coat of shellac applied to it. As many coats should be applied as is seen to be necessary until the pores of the plaster become filled, and shine or gloss appears. The joints of the pieces must be oiled over the shellac cover to avoid sticking together. All plaster parts must be well shellacked; this applies also to the outer shells of gelatine moulds.

Casting.— Casting by means of a gelatine mould requires more care and skill than casting in a plaster mould, for the gelatine is very sensitive to heat, and certain kinds will even melt at comparatively low temperatures.

It may be stated again that all parts of the mould must be well oiled before pouring in the plaster, and care should be taken after the plaster has set and begins to feel warm that the mould is opened and the cast taken out before the gelatine can melt.

Casting in a gelatine mould can be done successfully only in cool weather, for in warm weather the gelatine becomes soft and loses its toughness. If it is unavoidable, and gelatine moulds must be used in summer, ice should be employed to cool the mould and ice water should be used in mixing the plaster. Some kinds of gelatine stand more heat than others, and the finest casts result if the gelatine is of the kind to allow the casts to set and cool within the mould.

In cold weather it is advisable to expose the filled mould to the cold air and to take the cast out of the mould when cold. This allows the mould to cool together with the cast and the mould will therefore keep its sharpness. After every cast the gelatine mould should be brushed off with fine French chalk ("soapstone") which removes the surplus of oil and other matters which tend to reduce the sharpness of the surface.

Casting in plaster moulds is done in the same manner. In all cases care must be taken, that the air on the bottom of the mould is allowed to escape. This safeguards against air holes in the finished cast. The plaster should be mixed thin enough to run freely into all cavities of the mould. For heavy casting the plaster may be used somewhat thicker than for light casting; the mould should be shaken gently so as to force the plaster into all parts of the mould.

A few words may be said about reinforcing the casts. All casts should be strengthened by the use of iron rods, wire or burlap; and care must be taken that the wires are fashioned after the shape of the mould so as not to show on the outside of the cast. In delicate and thin casts it is practical to cover the shaped wire first with a coat of plaster, so that if the wire should become shifted in casting it will be sufficiently coated not to show.

Strong rods may be used in large casts, also in the heavy shells of the moulds. The latter can be made very strong and durable by laying burlap and wire gauze in sheets in them, while the plaster of which they are composed is still soft. The placing of the wires in the moulds must be arranged in a way to avoid shifting by the inpouring of the plaster.

Unless a uniform white is the color required in the cast, the plaster for all casting should be mixed with a thin solution of dextrine (about one pound of dextrine to two gallons of water). This mixture makes a much stronger and tougher cast than when the plaster is mixed with clear water; the mixture however darkens the plaster a trifle.

To increase the strength and durability of the casts the latter, when perfectly dry, may be saturated with a gum or a dextrine solution.

To make the casts damp-proof I recommend that they be allowed sufficient time to soak in a thin solution of shellac. The latter makes the casts and especially the surface, very hard. All casts, treated in this manner can be easily tinted and painted, since the pores of the plaster are closed.

A simple method of casting odds and ends and such objects of which only one cast is required — as may be the case in restoring missing bones — is that which we introduced many years ago in our laboratory as I have already mentioned very briefly in my preliminary paper; I now take the opportunity to explain this method more fully.

Modeling clay, such as that known under the name of plastiline, is of the greatest use in moulding such objects as those just mentioned; and where a not too accurate cast is required, it is a great labor and time saving method. The clay should have the proper consistency, neither too hard nor too soft. The clay block to be used should be of the size and thickness required. The bone to be cast must be coated thinly with glycerine to prevent it from sticking and then pressed with its median line into the clay, that is in such a way that the object can be lifted out of the mould without altering the impression. Before making the top half of the mould the bottom should be painted with glycerine to prevent the sticking of the two halves together and a few impressions or notches made with the finger where the top mould is fitted on, to aid in holding the two parts in position after the specimen is taken out.

In making the second half of the mould the clay should be pressed on the lower half in thin sheets to allow a good impression to be made, and when sufficiently strong, so that the mould will not lose its shape on lifting off, marks should be made with a pointed tool over the edges where the two parts of the mould fit together, so as to enable the caster to bring the parts in proper position again after the object is removed. The plaster should be poured in the two moulds separately up to the edge of the impression, and when sufficiently set, so that the plaster does not run when tipped over, both moulds should be slowly pressed together until the marks of the two moulds fit accurately.

When larger bones are cast in this way it is often necessary to have the mould of three or more parts; and with some skill and care a fairly good cast can be obtained that is accurate enough for ordinary purposes.

To replace missing bones it is often desirable to make the cast larger than the bones from which the cast is taken. This can readily be accomplished as far as the circumference is concerned, by moving the bone a little in the impression to make the latter larger; and the length may be increased by cutting and stretching the shaft. Should the bone be in two pieces it pays to stretch it to the required length. In this way the two ends will be moulded pretty accurately, which is the main object in modeling, for the middle part, or shaft, can be shaped easily.

A number of small bones, such as foot bones, etc., can be cast together in a single mould, a process which saves considerable time.

The larger clay moulds can be stiffened by the use of strips of wood or with iron rods or wire.

For very accurate and sharp casting sulphur is often used instead of plaster. Sulphur produces a much sharper cast than plaster does and for all small casts is very desirable. The mould used in sulphur casting should be made of fine potters'-clay of neither too hard nor too soft consistency. The mould is prepared in the same manner as that made of plastoline, that is by pressing the specimen to be cast into the clay.

If more than one duplicate is required the mould should be constructed in a sufficient number of parts, so as to allow the casts to come out of the mould freely without injuring or changing the form of the impression. If several pieces to a mould are required, the separate parts should be treated in the same manner as in the case of plastiline that is where the parts join together, glycerine or turpentine should be applied to prevent sticking together.

To hold the parts of the mould in place, a light plaster shell should be applied to its outside. To produce a very sharp cast only a thin coat of oil (best turpentine) should be applied to the specimen to be cast.

Sulphur must be cast very hot, melted until it begins to smoke (not to burn) to make it run freely, which fact makes a plaster mould of no use since the sulphur would burn the plaster. The sulphur has to be poured in the mould in the same way as gelatine is, that is a hole must be left, and clay should be built around in funnel-shape where the sulphur is poured in. Care should be taken that the pour-hole is placed so that it interferes as little as possible with the form of the object, as in all casting it is necessary to shake the mould slightly, to allow the air in the bottom of the mould to escape.

Several small casts can be produced from one mould at the same time, if a small channel between the separate specimens is cut out of the mould to act as a connection, and such should always be cut at a place where the least harm is done to the form of the cast.

As stated above sulphur produces a very sharp and durable cast, which can be colored to suit; and the sulphur cast is very good for casting any small specimens such as teeth, foot bones, and other small bones, where a very accurate cast is required.

Brain Casting.— It is often of great importance to science to know the size and form of a brain cavity, since many theories are more or less based upon the brain capacity of an animal; therefore it often becomes necessary to make a cast of the brain cavity. A few words may be said in regard to this kind of casting and how the best results may be obtained.

As I have mentioned on another page (p. 299) it has happened within my experience that for some particular reason a brain cast had to be taken out of the cavity through the *foramen magnum.* The brain however in comparison to the skull was a very small one, and the foramen magnum was relatively large. This is in any case a very difficult operation and should be avoided wherever possible, and therefore the brain case should be in several, or at least in two parts.

A skull, of which the brain case is to be cast, when broken in such a place that the brain case can be separated, even though in unequal parts, is often very suitable for this purpose, provided the cavity is in normal condition and perfect. If the brain case is intact in the skull, it should be cut in such a way, that one half of the case can be lifted off. A cut is made in a straight line through the middle of the skull from the foramen magnum to the front of the brain case, that is to the olfactory lobes, and then from there cut across at a right angle on one side of the skull only; that is from the middle of the skull on one side, it leaves one half of the brain case in the skull and the other in the piece cut out. This enables us to clear the cavity thoroughly of matrix or dirt and to shellack and oil it in the same way as other bones to be cast. Before the two halves are placed back in position care must be taken to stop up all foramina with clay in such a way as to let the base of the foramina show in the shape of warts (from $\frac{1}{4}$ to 1 inch long) on the cast so as to show their respective location.

For all brain casting the gelatine should contain more glycerine than that for moulding since greater elasticity is required; and in case the gelatine cast is not reproduced in plaster it is preferable to mix but very little water with the gelatine so that the cast may keep its size and form a long time when kept in not too warm a place — since warm weather will deform the cast. Any desired color may be given to the gelatine cast by mixing the gelatine with dry colors the same as used in coloring plaster.[1]

In duplicating brain casts a plaster cast has to be taken from the gelatine cast first. The plaster mould should be made in two parts from the gelatine cast which allows the gelatine to separate easily from the plaster mould. The latter must be shellacked and oiled like any other plaster mould. After being filled with plaster and allowed to set firmly, the mould can be taken off in pieces, as a so called "waste mould" then the plaster cast may be treated like any other object and a gelatine mould should be made to cast from.

Reproducing Bones in Papier-Maché.— Reproductions in *papier-maché* are frequently made of larger bones and especially of restorations, in order to reduce the weight of the reproductions. The casting in *papier-maché* is a slow operation and has to be done well in order to obtain good results. This method is of minor importance in a palæontological laboratory since plaster casts can be made hollow and strengthened with wire cloth or burlap, which makes them almost as light as those reproduced in *papier-maché.*

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[1] Mr. J. W. Scollick, preparator in the United States National Museum, at Washington, published some years ago in the Proceedings of the National Museum, Vol. XVI, p. 61, a short note treating the subject of making gelatine casts. In describing the reproduction of fowls' combs, he says:

"Preparations with glue (or gelatine) for their basis having been used successfully for anatomical models, casts of fishes, etc., it seemed probable that this substance could be employed with advantage for artificial combs. After considerable experimenting the following combination was found to give good results:

	Ounces
Best Irish Glue	4
Gelatin	2
Glycerin	4
Boiled linseed oil	¼

" The glue and gelatine should be softened in 60 per cent. alcohol, only enough being used to barely cover them. The object of this is to introduce as little water as possible into the compound.

" The glue should then be melted and the glycerine stirred into it, together with a few drops of carbolic acid or oil of cloves.

" Casts made of the above material have lain exposed to the sun for an entire summer and been kept in a warm, dry room for the rest of the year without shrinkage or other change of form.

" Owing to the small proportion of water, this compound is so dense and dries so rapidly that it is poured with difficulty into the mould. . . .

" By slight modifications in the proportions of glue and water and by varying the method of manipulation, casts may be made of a great variety of objects, and the compound is of course, equally available for gelatine moulds.

" It must be borne in mind that the addition of more water, while increasing the fluidity of the melted mass, also increases the amount of shrinkage of the cast, since, sooner or later, the water must dry out; still, in most instances, a small amount of shrinkage is of little consequence."

If bones are reproduced for mounting as a skeleton, plaster casts are preferable, since in mounting iron rods can be passed through the bones and fastened inside with plaster, which cannot be done with a cast of *papier-maché*. However, it may become necessary to reproduce a very large bone, pelvis or skull in *papier-maché* and I therefore will treat the *papier-maché* method very briefly.

In *papier-maché* casting plaster moulds are necessary; since the mass used for casting has to be pressed and pasted solidly to the mould, this would make a gelatine mould useless. These plaster moulds should be treated in the same manner as when casting in plaster, that is, the mould, after being sufficiently dry, must be well shellacked, and then a very thin coat of oil applied — not enough, however, to soak into the paper.

For small and delicate casts I find it practical to use blotting paper or other soft paper, soaked in a thin paste of liquid glue and whiting and applied to the mould in the same manner as wall-paper is handled. The paper should be cut into suitable strips and successive layers be applied until the cast has the required thickness. Care should be taken that the paper becomes well shaped to the mould, which easily may be accomplished with the fingers and brush. This, of course, can only be done if the mould is open, that is in parts. With most casts it is sufficient if the mould consists of two halves; however, it may become necessary, as in the case of a large skull, in order to free the cast from the mould, that the latter be made in several parts.

Wherever paper pulp is obtainable, as in paper mills, etc., I find it most practical to complete the cast with it. After two or three sheets of soft paper are pasted on to the mould, the pulp (out of which the water has been pressed) should be mixed well with the paste I mentioned above (liquid glue and whiting in which the glue may be thinned down to half its original consistency), kneaded to a dough-like consistency and added on to the cast over the paper layers, until it becomes of the thickness and strength required.

To produce a sharp impression of the texture of the bone the outer layer of paper should be of a very soft, thin kind so as to work in close to the surface of the mould, and the paste should not be of too thick a consistency. The casts should be allowed to dry in the mould to avoid warping afterwards, and for larger casts the mould may be constructed in such a way that the parts overlap one another, being flush on the outside. This enables the caster to make a strong connection between the single parts. The latter should be fitted together tightly and fastened with a strong pulp mixture.

For very large casts it is advisable to press the pulp-mixture directly to the surface of the mould, which may be further strengthened with wire netting in the same way as in plaster casting.

If paper pulp is not obtainable, any kind of old, soft paper, soaked in water, and cut and ground in as small particles as possible, will answer the purpose, especially for larger casts. Some *papier-maché* casters use flour paste to mix with the paper or pulp, others use book-binder's paste for pasting the layers of paper together; either of these processes may be practical for a certain kind of casting, but a mixture of strong glue-water and whiting, not too thick, makes a paste which is most reliable. Liquid glue is best since a mixture with ordinary carpenter's glue requires to be kept at a temperature high enough to prevent becoming stiff. By some experimenting one will learn the right kind of mixture to use; too much glue in the paste has a tendency to make the cast crack when dry.

To give the paper cast a greater resistance and to make it damp-proof it should be well soaked with a solution of shellac, when dry; and little defects on the finished cast may be remedied with a thin mixture of shellac and whiting, which also may be colored to suit. A colored cast can be produced if dry colors are mixed with the material used in casting, such as paper, pulp, etc.; this has the advantage of not showing the scratches on the finished cast if roughly handled. The shellac coating on the cast makes a good size for the paint, although boiled linseed-oil or varnish may also be applied to harden the surface of the cast.

In making "waste moulds," that is moulds that are only used once, it is advisable to apply close to the specimen a thin coat of plaster, tinted with sienna or green and when set, to complete the mould with white plaster. This colored layer will help to indicate the nearness of the cast when the mould is being removed.

Mounting Fossil Skeletons.

In my preliminary paper I briefly mentioned the subject of mounting but did not have the opportunity then to say anything about the most important thing in a mount, namely the pose of the skeleton.

A large number of fossil skeletons have been mounted within the past fifteen or twenty years in the museums of America as well as in those abroad, and I dare say there is still left a wide field for improvements from both the technical and the artistic standpoints. Going through our exhibition halls, I often feel a strong temptation to make changes in our former mounts; changes, which, I am sure, would improve the naturalness of those skeletons immensely.

It may be stated, however, that fifteen years ago the making of instantaneous photographs had not been developed to the perfection it has attained to-day. In those days photographs of animals in motion were rarely seen, and even harder to obtain.

It is impossible, it seems to me, for the eye to observe all the movements of an animal closely and to apply these observations by mere memory; but the camera will catch what the eye cannot, that is, it will record the position of every part of the animal's body while in motion.

During the past eight or ten years we have employed in the American Museum photographs of living animals as guides in the mounting of fossil skeletons. For this purpose the photos of such living animals were selected

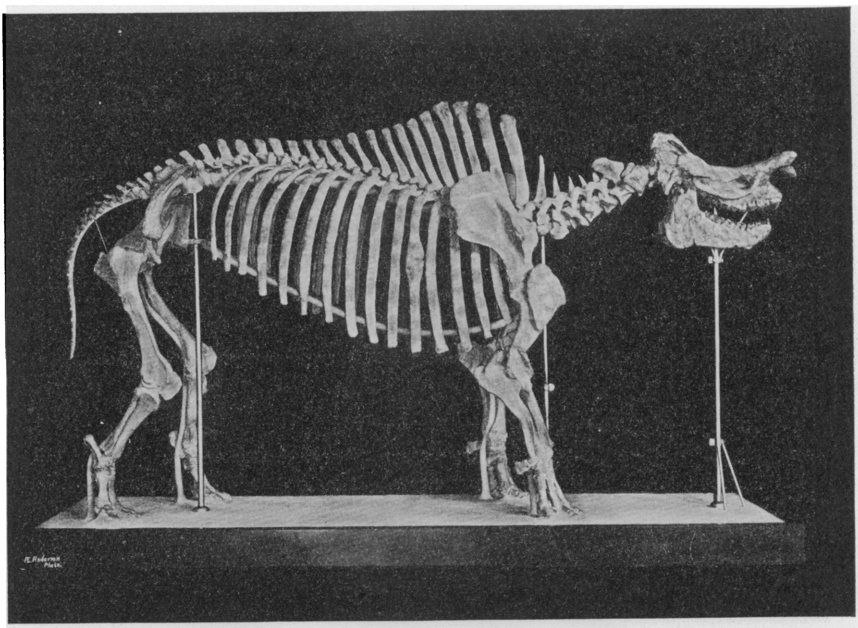

Fig. 8. Skeleton of *Titanotherium.* Old style mounting; supports not concealed as well as in later work.

as resembled the fossil skeleton in hand most closely, as far as form and character were concerned.

In mounting fossil skeletons of horses, camels, deer, rhinoceroses, elephants and so forth, good guides can be obtained from the living forms, and any pose can be studied with absolute accuracy from instantaneous photos of the living animals. There are, however, extinct animals, that have left no survivors of their family: their skeletons require a careful study in order to ascertain the pose of the animal in life, and in our Museum this is generally determined after careful studies by Professor Osborn and members of his staff. In the case of these a student of comparative anatomy finds great help in studying the attachments for the muscles to the bones, and I may say that in a great many instances the approximate pose of a skeleton can only be determined from the rugosities on the bones, indicating the stronger muscular attachments, from the facettes of the joints, and from the general shape of the vertebræ and other bones.

In the case of reptilian skeletons where the articulations of the joints are generally rather indistinct, the positions of certain bones can only be determined by making careful memoranda recording the position of the bones as found in the matrix. Without such memoranda it is impossible in many

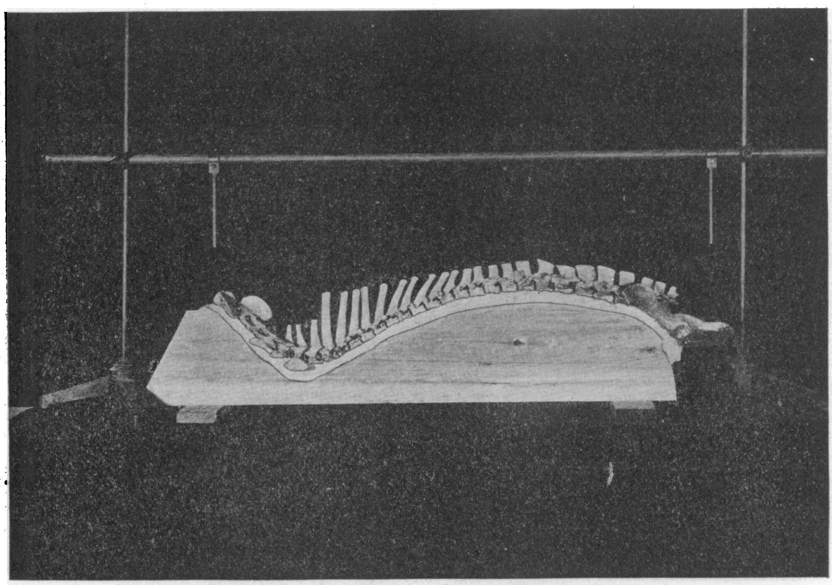

Fig. 9. Temporary wooden support for back-bone, with uprights and horizontal bar.

cases ever to bring such bones to their relative positions, and this will make it difficult to represent the natural form of the skeleton.

Arranging the Skeleton for Mounting.— The skeleton to be mounted should be completely restored if the condition of the specimen makes it necessary. The vertebræ may be mounted on a wooden frame, shaped to the curvature of the backbone in the living animal. (Fig. 9.) The vertebræ then should be pressed in a strip of clay, which is laid over the board, so that slight changes can be made into the positions of the vertebræ. For small skeletons one board used edgewise is sufficient, for larger skeletons two boards may be fastened together leaving a space between them of two to six inches (according to the size of the skeleton) and put up edgewise in such a way as to form a saddle for the vertebræ. This makes a good temporary support, and by the aid of wooden blocks and clay the vertebræ can be placed very accurately. Before shaping the rod which is to support the backbone, the vertebral centra should be freed from all obstructions on one side, so that their position be accurately determined and so that the support can be bent and shaped to fit the bones. Figure 10 represents a skeleton temporarily set up for studying the pose.

Here I may mention that where the support or rod is to run through the neural canal, it should be shaped over the transverse processes or rib facettes on the vertebræ, so as to give the exact shape required. If a rod is employed to hold up the vertebræ from the bottom, as may be the case in

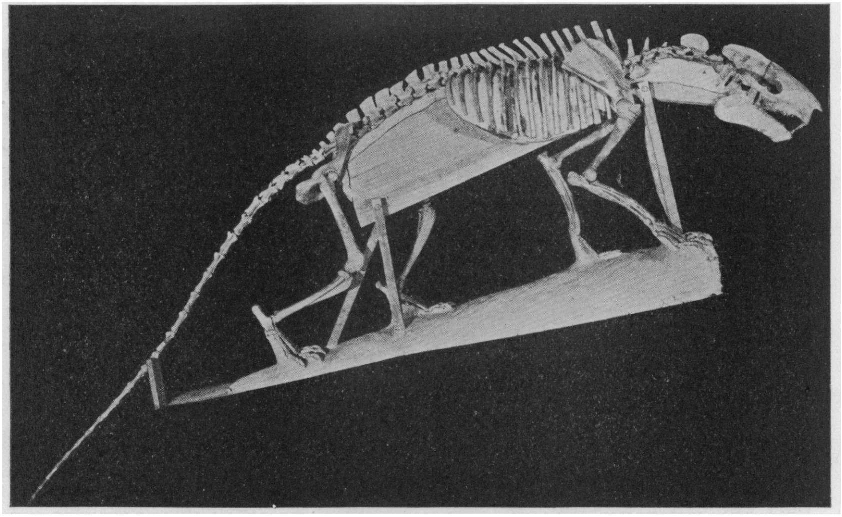

Fig. 10. Skeleton temporarily set up, for studying the pose.

mounting very large skeletons, or of skeletons in which it is desirable that the bones be detachable from their respective supports, the rod should be shaped to fit the bottom of the centra as closely as possible.

My intention is now to go somewhat into the details of the mode of mounting skeletons so that every bone can be detached for study, to be cast, or for any other purpose.

We have mounted a number of skeletons in the American Museum in which the vertebræ fit in a plaster-, or in two or three cases, in a metal-bed; in other words the plaster or metal is cast on the bottom of the centra allowing enough support to hold the vertebræ firmly in their places. This is executed in the following manner:

After the vertebral column has been placed in proper position on clay, a thin sheet of plastiline may be pressed on the top of the vertebræ, covering the spines and neural arches enough to hold the column in position. A layer of plaster may be put over the smooth surface of the clay to strengthen the support and this can further be reinforced by an iron rod, set into the plaster. This makes the vertebral column a solid body, which can be lifted from the clay underneath. Now, when turned over, bottom side up, a channel may be built with clay on the sides of the centra, in which the plaster or metal, whatever may be used, is poured, which will leave, when set, the impression of every vertebræ. Before the plaster or metal sets, the supports for the backbone (a soft steel or iron rod) of the required thickness and shape, must be pressed into and become covered with the soft matter, which was poured over the vertebræ. When set and taken off the column, it may be cut and shaped in such a way as to leave one side of the centra free to the middle line, so that the side view is not obstructed on one side (Plate LII A). However, enough imbedding must be allowed to hold the vertebræ firmly in position. It may be necessary to mention, that before pouring the plaster, etc., on the centra, care must be taken that the spaces for the cartilage between the vertebræ are stopped up with clay to prevent the mixture running into them.

For small skeletons I can recommend casting the backbone support of fusible metal, a composition of three parts bismuth, two parts tin and one part lead, or of bismuth three, tin one and lead one. This composition melts at a comparatively low temperature (in boiling water), and has but very little shrinkage. The channel for this casting should be built of potters'-clay, since plastiline will melt somewhat, from the hot metal. The bones should be painted with glycerine instead of oil and the backbone support put in place before the metal is poured. This metal, however, is not adaptable for large skeletons, since, when cast in large lengths, it would have enough shrinkage to lose accuracy.

In a skeleton of a large dinosaur, *Diplodocus,* which is mounted in the Carnegie Museum at Pittsburgh, the backbone is supported in the above manner; but the castings were made in sections of about six feet each to make up for the shrinkage. The casts were first made in plaster and then cast in steel and the sections spliced together, an operation which can be easily accomplished with iron or steel, but not with soft metal.

There are numerous other methods for mounting the backbone of a skeleton, so that the single vertebræ are detachable. Those employed in our museum I will here briefly discuss. The rods to support the backbone, that is those which run under the vertebral column, may be of different shape and form to suit individual tastes; round, half-round and square have been employed in the American Museum, and I will say, the half-round style, wherever strong enough, is to be preferred, since it can be shaped to the bones closer than the other styles (Fig. 11, E).

When the vertebræ can be bored with a good steel drill, it is practical to rest them on vertical pins of the required size, which may be fastened to the backbone rod either by fittings, which slide over the rod, allowing the vertebræ to be moved to and fro, or to be screwed tight to the rod, which makes them stationary.

The latter method is not practical with many skeletons, especially those in which the zygapophyses are tightly interlocked, since it becomes almost impossible to remove one vertebræ without moving the adjacent one, a fact already referred to in my preliminary paper.

As shown in the illustrations (Fig. 11) the fitting or sleeve, which slides over the bar, can be cast of bronze or iron very

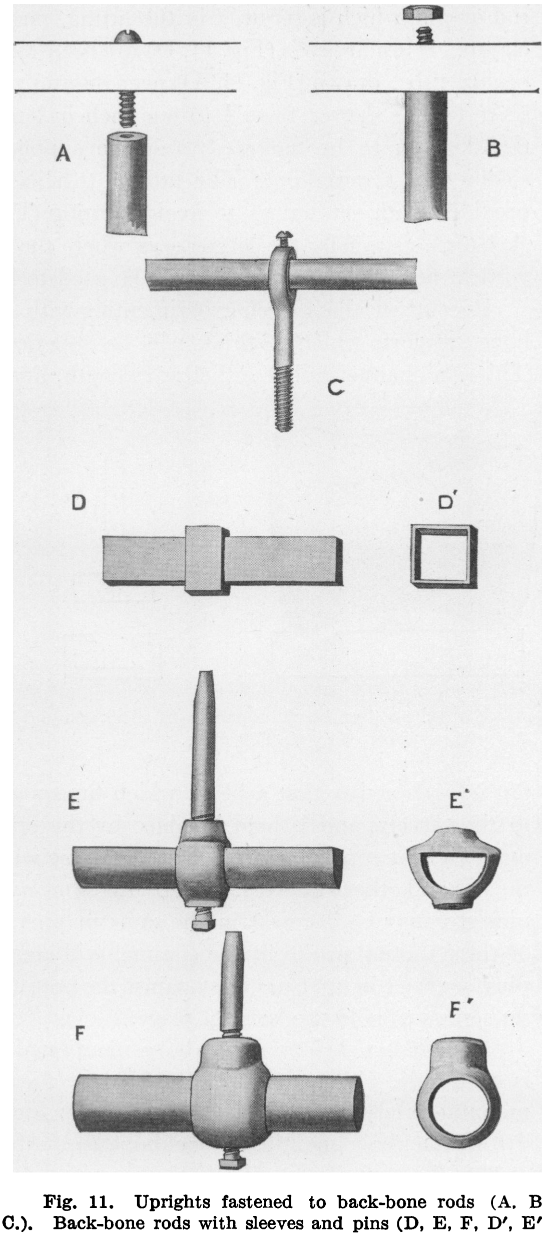

Fig. 11. Uprights fastened to back-bone rods (A, B, C.). Back-bone rods with sleeves and pins (D, E, F, D′, E′, F′).

lightly. A pin can be screwed in to hold the vertebræ and it can either run into the holes in the centra, if they can be bored, or if too hard to bore, the rod or pin, which is screwed in the fitting, may be split so as to serve as a clamp. If square rods (Fig. 11, D) are used for backbone supports a square bronze tube, drawn (Fig. 11, D) over the rod to fit, may be cut in pieces to serve for the sleeves, from ½ to one inch in length, according to the size of the skeleton to be mounted; and the supports for the vertebræ may be soldered or screwed on. The fittings to slide over a round rod must be provided with set screws to avoid turning (Fig. 11, E, F); also in those skeletons, especially the larger ones where the backbone has a more or less vertical position, set screws should be used to hold the sleeves in place.

Recently we have been experimenting with an entirely new style of backbone support, which I think will be superior to many others (Fig. 12). This is a channel rail of sufficient strength, lipped on both sides of the open

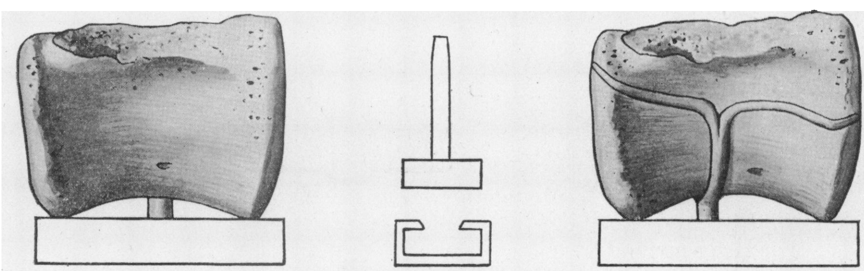

Fig. 12. A, Channel rail support with block and pin; B, vertebra bored, with pin inserted; C, vertebra supported by pin split twice.

top in such a way that a block which fits snugly in the channel, is allowed to slide freely, and is held in place by the lips above (Fig. 12, A). This makes a neat support, since it does not show any rings, etc., on the outside of the rod and otherwise works exactly the same as the sleeve fittings, that is the pins etc. may be fastened in the same manner. Ordinary square bolt-nuts of the required size to fit the channel will answer for this purpose, and the pins, screwed in tight to press against the bottom of the channel, will serve as set screws to hold the bolts in place.

For smaller skeletons the above mentioned channel bar of hard bronze is advisable. This may be obtained at factories where brass tubing is manufactured; for large skeletons, however, steel or iron bars are preferable.

All the above mentioned backbone supports should be reduced in diameter in the region posterior to the sacrum; and the tail support should be tapered gradually.

The skull can be supported from the backbone rod by adding attachments for holding it in position. In larger skeletons it may be necessary to use an additional brace coming from the vertical rod, or even an extra upright as in the case of very large skeletons.

The neatest support for the backbone is a rod running through the neural canal, that is, if the latter, when cleaned is large enough to allow a sufficiently thick rod to pass through. This method is practical with all mammal skeletons and also with reptiles of not too gigantic a size; it will, however, prevent the dismantling of the vertebral column.

The space between the vertebræ may be filled with plaster or *papier-maché*, colored like the matrix in which the skeleton was imbedded. This makes the backbone rigid and strong, and the plaster etc. between the vertebræ may be bored for fastening the ribs. In order to hold the vertebræ in their proper places I generally fasten a copper wire around the rod running through the canal, twisting it once or twice, with a loop between the vertebræ imbedded in the plaster. This holds each vertebra close against the rod.

Uprights.— The mounted vertebral column has to be carried by uprights or vertical rods, except in the case of very small skeletons in which the backbone may be supported by the fastenings that hold up the limbs (Plate LIII). With mammal skeletons two uprights are, in nearly all cases, sufficient for support. The one in front should have connection with the vertebral rod between cervicals six and seven to allow space for the sternum; and the rear one should be between the last lumbar and first sacral vertebra.

In the case of very large mammals, such as the mammoth or mastodon, it becomes necessary to employ an extra upright to support the skull. The fastening of the upright to the backbone rod can be done in various ways: (1) By boring the horizontal rod, allowing the upright (the diameter of which should be reduced here) to pass through the hole until reaching the shoulder on the upright, made by the reduction of the circumference of the latter, the upright then being tightened by a nut on the top of the horizontal rod (Fig. 11, B). (2) By boring the backbone rod and boring and threading the upright, then screwing both together by a machine screw (Fig. 11, A). If boring the horizontal rod might weaken it, a button-hook shaped pin may be used, which hooks over the backbone rod and is fastened by a set screw so as to stay in place, the lower end being threaded and screwed in the hole in the upright (Fig. 11, C). The latter style is only adapted to skeletons where the rod runs through the neural canal.

In mounting larger reptile skeletons the number of uprights must vary with the size and bulk of the skeleton. This matter I shall return to later.

Mounting the Ribs.— After the vertebral column is mounted in natural position and the uprights fastened to a temporary base, the next thing will be the placing and fastening of the ribs. As to their natural position that must be left to the preparator, like the questions of the form of the backbone, the pose of the limbs and feet; these matters depend entirely upon the knowledge and the amount of special study of nature by the preparator.

To support the ribs I find it practical in nearly all mammal skeletons to fasten the rib supports in front to the upright; in the rear to the backbone rods, either between the first and second or between the second and third lumbar vertebræ, although this is not the rule with all skeletons. If the front upright is reduced in size at about the height of the chest, the shoulder formed acts as a support for the rib-rod which, when shaped close to the upright and screwed or riveted to the latter is very strong. A neater appearance, however can be obtained if the upright (which is of one size in its whole length), is filed out all around its circumference to the thickness of the rib-support and the latter fitted into this slot neatly and screwed fast (Plate LII, B). The latter method applies principally to smaller skeletons.

The rear ends of the rib-supports I generally fasten in this way: an extra flat piece of soft steel of the proper size is shaped over the backbone rod and screwed to the latter allowing on each side enough projection for two screws, with which the rib-supports are fastened firm to the cross piece.

For small skeletons the rib rods may be of flat steel; for larger ones half round or channel rods are preferable — the latter with the channel inside leaves a suitable space for the nuts with which the ribs are fastened to the rod.

Fastening the Ribs.— All ribs that are too hard to bore should be held together and reinforced by a wire running along the inside and imbedded in plaster, which may resemble the color of the matrix in which the skeleton was found. The plaster can be cut and shaped so as to cover only a narrow strip of the bone. In mounting very small ribs the wire support may be left a little longer on the top end so the projecting part may be bent to serve as a hook which may be fastened between the centra of the vertebræ. In mounting larger ribs it is practical to have the wire support the exact length of the rib and a somewhat lighter piece of wire should be imbedded with plaster on the head of the rib, which serves as a fastener for the top.

If the space between the vertebræ, representing the cartilage, is filled with plaster or *papier-maché* it becomes easy to get a hold for fastening the ribs by boring holes in the plaster etc. If on the other hand the column is arranged so as to be taken apart when necessary, the ribs must be fastened in such a way that they can be separated from the vertebræ at will.

The lower ends of the ribs may be fastened to the supports either by screws, running through the ribs and the supports with nuts on the inside, or with a fine band fitted around the ribs and passing through two holes in the support, and clinched on the inside. A neat fastening can be obtained on small skeletons by twisting two small flower wires together which, when bent around the ribs and twisted on the inside of the rod is almost invisible.

Limb Supports.— Hard limb and foot bones which cannot be bored naturally have to be held up by rods of either flat or half round steel for al' moderate sized skeletons. Flat steel is preferable for the smaller skeletons since the narrow band-steel can be fitted snugly to the bone, and it is' moreover, least conspicuous. Half round rods are more practical for the, support of limbs of a more massive construction.

For very large and heavy limb bones such as those in dinosaur skeletons (as for instance in our *Brontosaurus* skeleton where the left femur weighs 850 pounds), a round Bessemer steel rod is the safest, since the half round steel is likely to bend at the joints unless it is of large diameter, which, however, would make the supports look out of proportion. In order to fit the supporting rods on the bones neatly, the limbs may be held up by temporary supports of strips of wood or iron to which the bones may be fastened in such a way that these supports do not interfere with the fitting of the permanent rod.

If the foot bones are mounted on a plaster pedestal (p. 328), the limb support may follow the latter closely to the base, where it should be fastened securely. If the foot bones are bored and mounted like recent feet, or if the isolated digits are supported by bands of steel, the limb supports may be carried under the feet as close as practical so as to make them the least conspicuous.

To reinforce the two sides of limb supports on the top the rod of the fore limbs may be fastened to the rib support first, then the two sides may be connected. This applies to smaller skeletons; with large ones it often becomes necessary to run up the rod, following the scapula and extending across to the backbone support where it may be fastened by screws.

The hind limb supports may run under the acetabulum and meet on the other side of the pelvis, where the two rods should be spliced together. In large skeletons it often becomes necessary to run up the limb supports on the inner side of the pelvis to the sacrum, where they may be fastened to the backbone support either with a screw running between the vertebræ, as may be the case when the rod passes through the neural canal, or directly to the rod, if running under the vertebral column.

The individual limb bones should be fastened to the supports by means of narrow and very soft band-steel or copper wire, which should be fitted around the bones neatly and fastened to the supporting rod by very small machine screws. The size of these bands of course depends upon the size of the rods employed. The more neatly they fit the bone the less noticeable they will be in the finished mount (Fig. 13). Fastening the bones to the rods by means of bands is advisable only for bones too hard to bore. Nearly all Pliocene and Pleistocene bones can be easily bored and in such cases it looks neat if the bones are fastened to their supports by screws. This can be done in this way: Brass tubing (which can be obtained in all sizes) should be inserted into the bones after a thread has been cut in the tube. The bone should be bored as deeply as possible so that the tube fits the bore pretty tightly. If the bone is porous and soft, the bore should be soaked with strong shellac before the tube is inserted to strengthen it and after being allowed to dry, the tube may be coated with a mixture of shellac and whiting which holds the tubes firm. The support should not be screwed on to the bone until the tube becomes perfectly set in the bore. The last mentioned method makes the handsomest looking mountings for skeletons in which it may be necessary to have the bones detachable, as one can observe in the American Museum from several skeletons mounted in this manner; on the other hand, when the bones may be stationary as with a recent skeleton, it is more practical to bore the bones and fasten them together by wires (Plate LII, B). All wires can be made invisible by selecting the proper place for their insertion; however, this must be left to the judgment of the preparator. The feet can be made very rigid, if after the bones are bored and the wires inserted, the joints and spaces between the separate bones are filled with plaster of the matrix color. Two wires should be allowed to run out of the carpus and into the radius and ulna two wires are also required to fasten the tarsus to the tibia and fibula (see page 329 for mounting of feet).

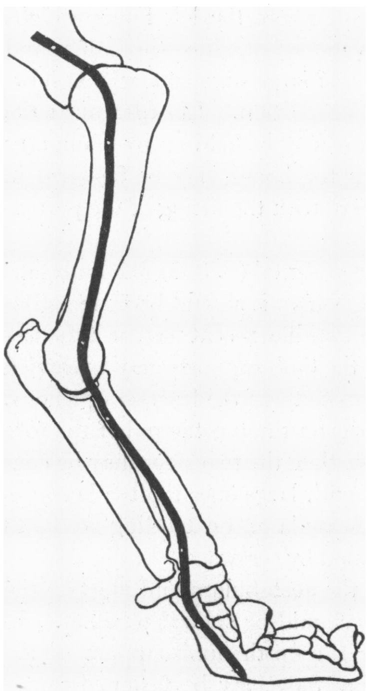

Fig. 13. Flat steel band fitting along inner side of limb, fastened to tubes inside the bones by means of screws.

For the elbow joint and for the scapula, in most instances, one wire is sufficient, whereas for the knee joint two should always be employed, to prevent turning. The wires should enter the limb bones sufficiently deep enough to hold them firmly together. For fastening the wires in the bones I prefer either shellac and whiting, or a mixture of liquid glue and plaster, in some instances gum and plaster may be strong enough. Sufficient time must be allowed for the wires to become fastened in the bones before they are handled, otherwise the joints may become loose.

Supporting the Skull.— The skull in nearly all cases requires extra mounting which holds it and the lower jaws firmly, allowing them to be lifted off their mountings. For small and light skulls which can be supported from the backbone rod, I generally use a flat rod which may be spliced and screwed to the backbone support providing the latter is square; if, on the other hand, the backbone support is round in diameter the skull support should be round at one end so that it can be threaded and fastened to the backbone rod by means of a plumber's coupling. Either one of these two styles of rods can be flattened out and lightened and the end may be split so as to serve as a fork in which the skull rests firmly. If required, other small flat cross bands may be screwed to the principal rod and fitted to the skull to hold the latter securely. The lower jaws can also be suspended from the rod above. If the skull can be bored, it is advisable to fasten two pins into the support to enter the skull, one in the region of the palate about on a line with the first premolar tooth, the other at the most suitable place in the back part of the skull. These pins should be arranged so that the skull can be lifted off easily. The lower jaws can be suspended in front and back by two light bands or wires coming from the main skull support. To support heavy skulls the mountings should be made relatively stronger, and where an extra brace from the upright is required, it should be so arranged that the latter carries all the weight. The cradle in which the skull rests may be constructed of a flat iron rod on which cross bands are fastened to hold the skull in position; the lower jaws may be suspended from this main support as indicated above. This cradle can be fastened to the brace or upright underneath by splitting the upper end of the vertical support which may be opened and screwed on to the cradle.

We introduced some years ago a very simple method for supporting skulls either on the skeletons or in single mounts. Two pieces of annealed brass rod are cut off the required length and split lengthwise at the ends so that the two halves when opened out at right angles to the unsplit part reach around from the median line of the palate in such a manner that they may be shaped close to the skull so as to hold it firmly. One of these should be in the front and one in the back part of the skull (Fig. 14). The two rods are threaded at the ends and screwed to a plumber's T, which can be screwed to the vertical support. If the two rods are slightly arched (not too much so as not to show under the lower jaws), they are stronger. For large skulls soft steel rods may be employed in place of brass.

The lower jaws may be suspended from the round rods either by a soft wire which runs through a hole in the rod and is twisted below, or by a small, flat band of steel which is either screwed or riveted to the rod above (Fig. 14).

In the mounting of small skulls the brass rods may be split twice so that the plumber's T becomes unnecessary. A soft brass rod of the required size is split far enough, so that the two halves may be opened and arched as in the foregoing method; the ends may then be split again and opened forkwise to serve as clamps for holding the specimens firm. If the brass is bent forward and backward too often it becomes hard and is likely to break off; this can easily be prevented by repeating the process of annealing. Brass becomes soft in being heated to a cherry red color and then being dipped into water.

The above method of mounting skulls applies to the skull on the skeleton

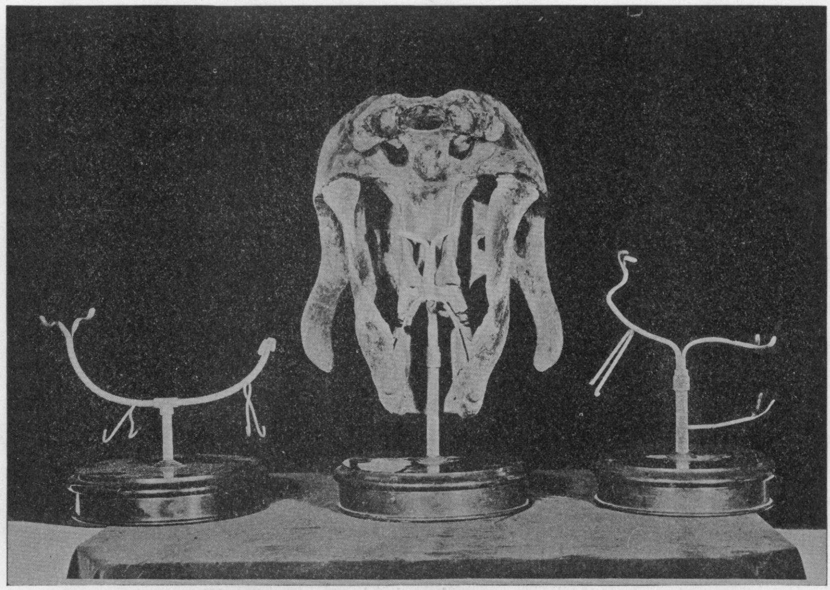

Fig. 14. Pedestals and mountings for skulls and lower jaws.

as well as to separate skulls; and as to the latter, that is skulls without skeletons, I may add a few words regarding the style of pedestals employed.

Many years ago we introduced in the American Museum a round pedestal for single mounts, such as skulls, limbs and feet and so forth. The base is made of two parts, a pedestal about two inches, with a platform one inch thick (Fig. 14). The platform rotates on little rollers inserted in the pedestal and is held in place by a pin or by the upright or stem which supports the specimen passing through the center. The specimen can be shown at any angle in the case by rotating the platform of the pedestal.

The stem runs through both platform and pedestal, bearing a rosette at the top and a lock-nut on the under side of the platform (Fig. 14). This makes the stem stationary in regard to the platform, and loose with regard to the base. By using another lock-nut at the bottom of the base, both parts will hold together.

However, the rotary motion can be brought about in the stem alone (Fig. 15, A), leaving the base or pedestal solid, a method which I observed lately in the Carnegie Museum at Pittsburgh. In this method, the vertical rod which supports the specimen consists of two parts which meet at about the middle. The lower stem being fastened solid to the base with a rosette at the top and a nut at the bottom. A sleeve of either brass or iron tubing is slipped over both halves of the stem fitting solidly over the lower part resting upon the rosette and somewhat more loosely over the upper stem so as to allow rotation. The sleeve should come up so as to almost touch the cross-mounting in which the specimen rests. The end of the two stems should be rounded off to allow free turning on each other in the sleeve in which they are held firmly; but the specimens may be easily lifted off.

Another method, similar to the above and somewhat more simple, is the following one (Fig. 15, B). A plumber's T can be employed with the vertical or outlet somewhat longer than the horizontal part. This probably would have to be made specially for some mountings. The lower part of this T serves as a sleeve as mentioned in the foregoing method, and requires only one solid stem or upright instead of two as described above. The T is screwed on to the mounting which supports the specimen in the ordinary way, and instead of being threaded on the vertical end as the ordinary T would be it is reamed out smooth and slipped over the stem, which is fastened to the pedestal in the regular way. This method has some advantage over the one just described, since it makes it possible to bring the specimens within an inch or two of the pedestal, that is the T may touch the rosette on the base, a circumstance, which cannot be accomplished with the method first mentioned.

A third method (Fig. 15, C) to bring about the rotating of the mountings in the stem or vertical support is to use for the upright a gas-pipe, which is fastened to the base and in which the upper part of the mounting rotates. This, however, is only adoptable in case a plumber's T is employed to which the upper mounting is fastened.

In mounting single limbs, the specimens should be treated in the same manner as they would be if mounted on a skeleton. The larger limbs, such as those of mastodon, mammoth or larger dinosaurs, require extra braces coming from the pedestals and fastened to the half round or flat iron, which runs along the bone. The single bones should be held in place with hooks, fastened to the bone supporting rod. The fittings which slide over the half round rods are very useful in this case, since they will serve to fasten the bone-supporting hooks as well as to fasten the vertical rod or brace (Fig. 16).

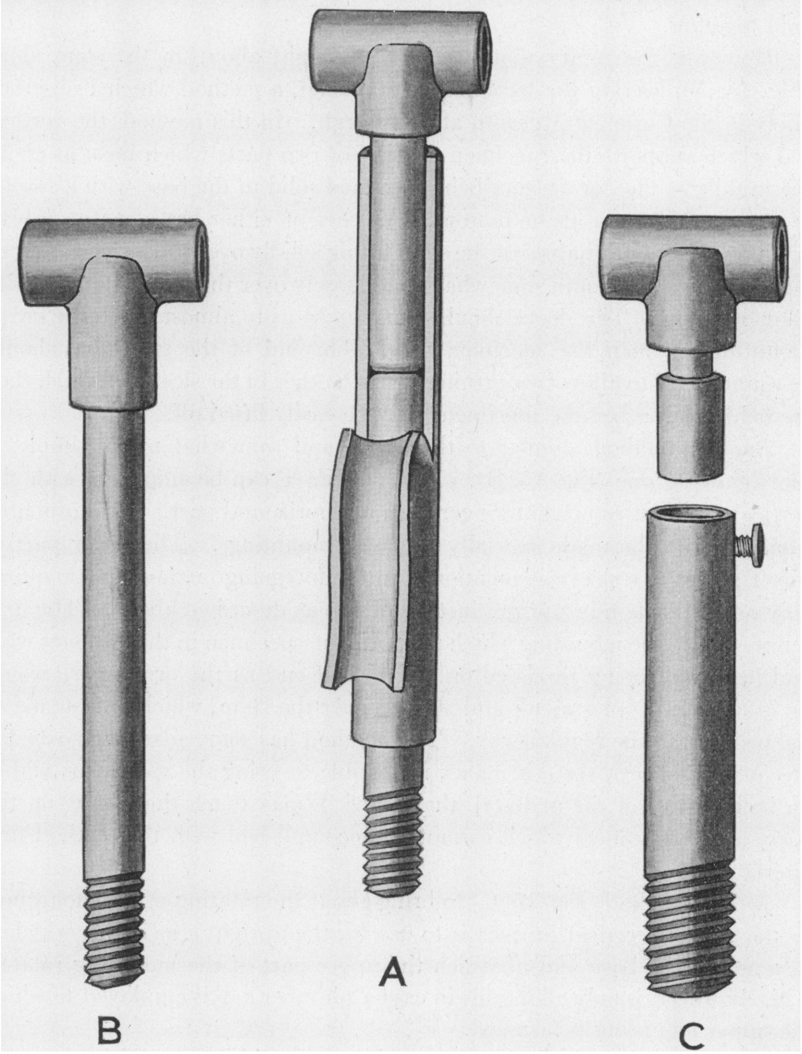

Fig. 15. Uprights for skulls and other single mounts.

At the close of the discussion of the mounting of skeletons, that is free mounts of various kinds, small and large, I may say a few words regarding the mounting of large dinosaur skeletons. I previously stated that in the

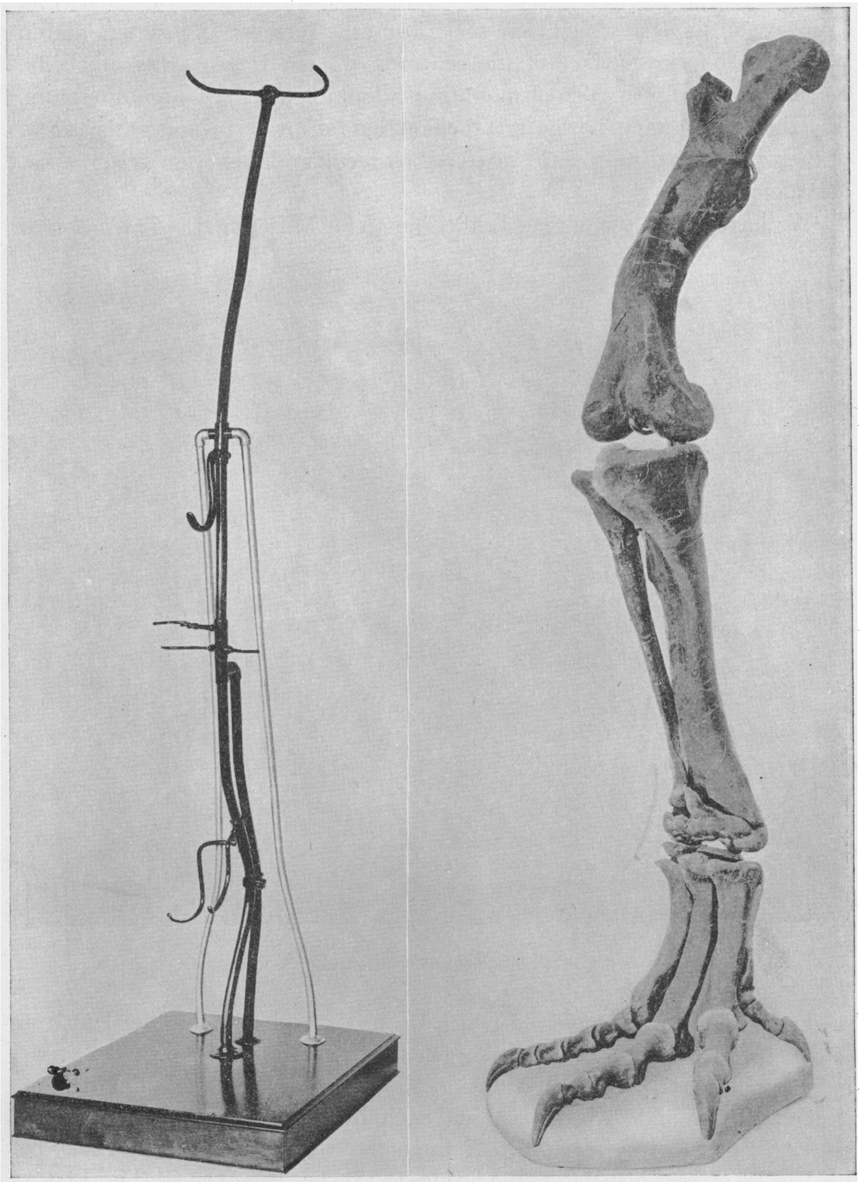

Fig. 16. Mountings and limb of *Allosaurus*.

Carnegie Museum at Pittsburgh there is a mounted skeleton of a large dinosaur (*Diplodocus*) in which the backbone support is of cast-steel, cast from plaster models, which were taken from the vertebræ in position, and in which the inferior surface of the centrum of each vertebra fits in firmly. I consider this a neat style of mounting, adoptable for very large dinosaurs. A slight disadvantage, however, is the fact that the lower surfaces of the centra of the vertebræ are more or less covered by metal and their view is somewhat obstructed.

We have recently mounted in the American Museum two *Trachodon* or

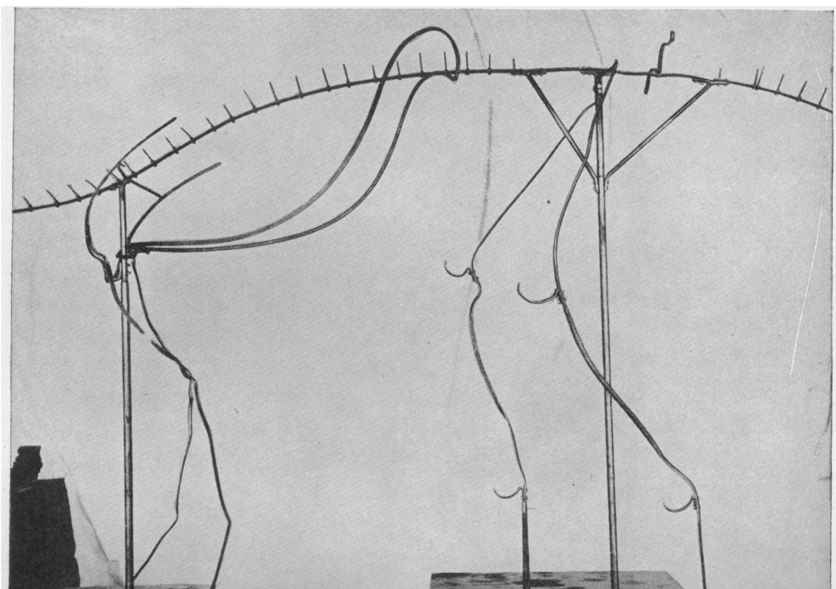

Fig. 17. Support of *Trachodon* skeleton.

duck-bill dinosaur skeletons in which we used the half-round steel for the backbone support, and which makes the least noticeable support of any we have had so far. As the illustration shows (Fig. 17) the fittings for the single vertebræ slide over the rod and each bone is held up by a pin which enters the hole in the vertebra. If the bones cannot be bored they may be held up by clamps fastened to the fittings as previously described (Fig. 12, C). This system to my mind is adoptable for larger dinosaurs by simply increasing the size of the rod and the fittings proportionally. The half round iron or soft steel can be fastened close to the shape of the vertebral column; but it should not be carried too close so as to obstruct a view of the centra. There are exceptions, however, where a round or a square rod may be more advisable.

For limb supports half round steel is preferable to round (with probably very few exceptions as may be the case with very heavy dinosaur limbs) since we found by testing that the half round steel carries a greater weight than had been expected. Mr. E. S. Riggs of the Field Columbian Museum at Chicago has supported the heavy limbs of *Brontosaurus* with half round steel, which holds them up firmly.

The supports for the individual vertebræ may come from the fittings which slide over the horizontal rod in the same manner as in mammal skeletons, only everything must be stronger in proportion. The fittings may be shaped at the top in such a way as either to allow the vertebral support to be screwed on similarly to a plumber's fitting, if round steel is used, or on the other hand, flat steel may be screwed down with machine screws. How to arrange the supports which run up on each side of the vertebræ cannot be described; this depends largely on the condition of the vertebræ and must be left to the decision of the mechanic. The same holds true for the supports for the pelvis and the shoulder girdle. The limbs may be supported in the same manner as single limbs as already mentioned.

These large dinosaur skeletons do not allow a uniform treatment either in the way of preparation, or of mounting, and no rules can be established to apply to all cases. Wherever such problems arise it requires some study as to the proper and most natural position as well as to the engineering part of the mounting, and it depends principally upon the individual taste of the respective authorities as to what style of mounting is preferred.

Slab Mounts.— Slab or tablet mountings are generally made for skeletons in which the bones are rather poorly preserved, crushed or where the ribs and limbs on one side are imperfect; exceptions however have been made, that is slab mounts have been made of skeletons which were perfect enough for free mounts. These slab mounts may be made in various styles and shapes. As represented in the American Museum collections are some which on top follow the curvature of the backbone more or less closely (Plate LIV, A); others are squared off, the rectangular background being large enough to take in the skeleton (Plate LIV, B). The mode of construction of the slab depends a great deal on the condition of the skeleton.

If a skeleton is found in more or less natural position and the bones can be left in the matrix it is almost always advisable to set them on the slab in the same way, with the least straightening of the skeleton. Our skeleton of *Aceratherium tridactylum,* mounted in this style, illustrates this method very well and is favorably regarded by many scientists.

The mounting of a skeleton in the above style is carried out as follows: The frame may be constructed of wood or iron, whichever is most practical. For very large skeletons, such as large fossil fishes or marine lizards (Mosasaurs, etc.) a strong, wooden frame which can be reinforced with irons at the corners, seems the most practical. The different sections are laid in the shallow, tray-like frame, where the surface of all wood must be either tarred or made waterproof by some other means to prevent dampness from penetrating into the wood. After the sections are anchored to the bottom of the frame by nails or wires, the missing parts of matrix around the sections or under them and all vacant spaces in the frame should be filled with plaster of the color of the matrix in which the specimen had been found. Loose bones, such as limbs, foot bones, ribs and so forth, may be held in place temporarily by means of clay or wire, until the plaster is built up from underneath and they become embedded in plaster which holds them firmly. To hold larger bones in place it may become necessary to fasten extra bands of wire etc. around the bones and into the plaster. Wherever possible the skull should be supported so that it is detachable.

There are many skeletons which are very rare and of unique character, in which sooner or later it may become desirable to take the bones off their mountings either for study or casting purposes. In these cases the bones will have to be cleaned and freed from matrix before mounting. It is also practical in most instances to do all required restoring on the bones before they are mounted.

The vertebral column is then set in clay or plastiline in the required position and each vertebra being pressed in with the inner side far enough to stay in place if the slab is in an erect position. This should be done in the same manner with the inner limb and foot bones. The bones, which were painted with glycerine before having been pressed into the clay, may now be lifted out carefully, so as to leave an accurate impression, and then a plaster, or gelatine mould made over the clay. If a plaster mould is made, a thin layer of tinted plaster should be applied to the clay first and then finished with clear plaster in the same way as any waste mould is made, as described in a former paragraph (page 306). The plaster mould should be made as light as possible and when sufficiently set and turned over, the clay may be removed, and after being treated like any other mould, the cast can be made of matrix-colored plaster and reinforced with burlap, wire gauze or metal rods, whichever the size of the slab may require. When sufficiently set, the plaster mould may be taken off in pieces like any waste mould; and the bones placed in their respective cavities. The limbs of the outer side should be mounted in the same manner as in a free mounted skeleton.

A gelatine mould requires somewhat more time, but is more reliable than a plaster waste mould. When the plaster mould is cut off from the cast, danger arises, that the latter may become injured by the chisel. This is avoided in using a gelatine mould, since it lifts off so easily. The mould has to be prepared in the manner previously described under moulding (page 300), that is a shell has to be made to hold the gelatine mould in place.

In several cases of slab mounts in the American Museum we have constructed a frame of iron pipes, which were screwed together in the corners with plumber's elbows, reinforced with cross pieces, and the inner space filled out with wire netting. Such frames are practical for mounting skeletons where no wooden moulding or frame around the border is required, since they appear like massive stone slabs.

This method may also be recommended for mounting skeletons in which the bones are partly in the original matrix. After the frame is completed, that is the wire gauze has been fastened to the rods, the sections of the skeleton may be laid in the frame, in the same way as with a wooden fence, and the plaster built under the specimens and all spaces filled so that the entire iron construction is covered with plaster. This style of frame may also be applied to mounting skeletons where the bones have to be detachable. In such cases the bedding for the backbone, and for the limbs and feet will have to be cast in parts and placed in the frame in position, where they may then be set in plaster so as to become fastened to the metal work.

Slab mounts made on iron frames can be made neater and lighter than those made in wooden trays with moulding around the edges (Plate LIV, A). The indoor temperature neither causes the iron to expand nor to shrink, and since the iron rusts in the plaster, plaster and iron become strongly combined; this makes the slabs very durable. I am convinced that large dinosaur skeletons, which have to be mounted in slab style, can be mounted with iron frames, arranged in suitable sections which can be fastened together so as to act as one solid body when in permanent place. The slab can be of a light construction, from one to two inches of plaster over the iron is sufficient to make the frame very rigid, and the heavy limb bones, such as those of dinosaurs can be fastened to the iron parts very easily and the slab as a whole can be fastened without the least difficulty. We may have the opportunity in the near future to make a mount of this kind in our museum.

Mounting Feet on Plaster Pedestals.— The mounting of foot bones in their natural position on plaster pedestals is very frequently done in natural history museums. The method is simple, quick, and since most animals have the largest part of the foot on the ground (*e. g.*, cats, dogs, bears, etc.) it seems more natural to see the bones on a solid block of plaster, than on any other support (Fig. 18). The feet may be mounted so that each bone can be taken off the pedestal separately. This is done in the following manner:—

The bones, after being cleaned from their matrix and, if necessary, restored, are mounted temporarily in natural position on a block of plastiline. In order to hold the bones in position when the foot is to be turned over for casting the pedestal, a very thin sheet of plastiline is pressed on the outside of the bones and a layer of plaster is spread over it, just heavy enough, when

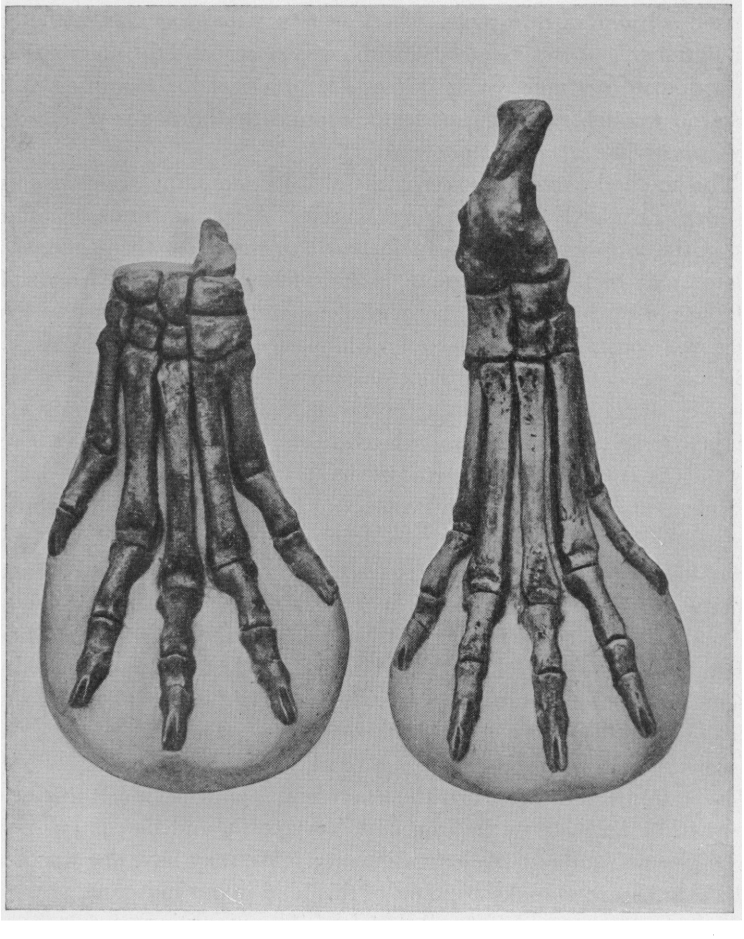

Fig. 18. Fore and hind feet of *Hyænodon* on plaster pedestal.

set, to hold the bones together. Then the plasteline block with the bones embedded may be turned over and the clay carefully taken off the bones in such a way that they are not disturbed or shifted out of their places. The bones may then be treated in the same manner as in casting, and a frame of clay should be built up to indicate the size and shape of the pedestal. The plaster, which is usually the color of the matrix, in which the bones have been found, should then be poured over the bones and when set, turned over with the bones. The top shell may now be removed and the bones cleaned from plastiline, etc., which is done easily with benzine or petroleum. Before the bones are placed in their impressions or sockets in the pedestal, the latter should be cut and shaped to suit, especially around the edges of the bone-impressions where a sharp cut helps to raise the bones from the pedestal and sets them off distinctly.

The above method of mounting feet may be employed also in the case of mounting skeletons, where the foot bones rest on plaster supports. If the feet are mounted with wires running through the bones, or with iron band supports as may be the case with very large feet, the latter should be mounted on a temporary clay-and-wood support, in natural position first and treated in the manner I have described, since an accurate position can only be obtained if the bones are held in their correct position while being turned over.

The Base for the Skeleton.— In the American Museum we have adopted almost exclusively in mounting fossil skeletons a matrix base, that is, a base which is covered with artificial matrix, or in other words, covered with colored plaster of the shade of the original matrix in which the skeleton had been found. This method is favored by most palæontologists since it is an improvement over the appearance of the fossil bones when mounted on a wooden base. The base is generally constructed of ordinary pine boards, framed with a better quality of wood, such as mahogany, etc. The frame should be deep enough to allow space for a nut beneath the bottom to fasten the uprights and for a shallow tray on the top of the platform from one half to one inch deep for holding the sheet of artificial matrix. This tray must be well tarred to prevent the moisture from penetrating into the wood and so save it from becoming warped or cracked. For larger bases it becomes necessary to employ heavier wood and to reinforce the bottom with cross cleats.

To prevent the cracking of the plaster, a sheet of wire gauze should be tacked to the bottom of the tray, loosely enough to allow the netting to become embedded firmly in the plaster. After the latter is shaved and smoothed it may be scratched and chipped either wet or dry to produce the appearance of a stone slab cut by a stone cutter (Plate LIV, B). Although exposed to the dust of the exhibition room these bases are easily kept clean, since they may be washed off easily. However, the style of bases is largely a matter of individual taste.

Machinery and other Appliances.

At the end of this paper I desire to say a few words more in regard to the tools and appliances employed in our laboratory. In previous pages (p. 288–295) I have mentioned the different tools which we have found in our experience most adaptable for certain kinds of work and a brief description of other appliances and machinery in use in our laboratory may be of interest to some readers.

I mentioned in my previous short paper [1] the installation of an overhead trolley system in one of our large laboratory rooms. This consists, as shown in Plate LV, of a steel rail, similar in shape to a railway rail, which is fastened to the ceiling. On this are trollies, to which hoisting blocks are attached, rolling to and fro freely.

The trollies can be obtained of different sizes, according to the weight they may have to carry. Ours are from one half to two tons lifting power. This system is of immense assistance in mounting large skeletons, especially of those of some dinosaurs, since the different parts can be suspended and moved easily from one end of the room to the other as well as raised and lowered to suit. But not alone for mounting skeletons, but also for moving, hoisting and turning heavy boxes and heavy specimens it is very useful.

For section cutting and especially for splitting brain cases where brain casts are required we employ a rotary diamond saw. This is a circular blade, made of thin, soft sheet iron, with fine cuts around the edge ($\frac{1}{8}$ inch long and $\frac{1}{8}$ inch apart) in which diamond dust is ground, giving the blade a sharp cutting edge when used with water, which is allowed to drip over the saw when operated. These saws are manufactured in different sizes to suit various purposes. If the diamond set edge has become worn off, the same blade may be used with emery powder. This however leaves a larger cut than the diamond saw does. We use this diamond saw attached to a large lathe. The latter also operates two carborundum wheels for grinding, a drilling or boring machine, a small turning lathe and a rotary saw, for splitting and cutting steel or brass. A two horse power electric motor is sufficient to operate all the appliances just mentioned (Plate LVI).

For forging we have employed a small sized gas-blast furnace (Plate LVI) with a blower which is run by a $\frac{1}{3}$ horse power motor; the forge is powerful enough to heat a two inch steel bar. Wherever compressed air is available the motor-blower becomes unnecessary.

A very useful and almost indispensable tool is the "electric drill." It can be obtained in different sizes for either light or heavy work. In our labora-

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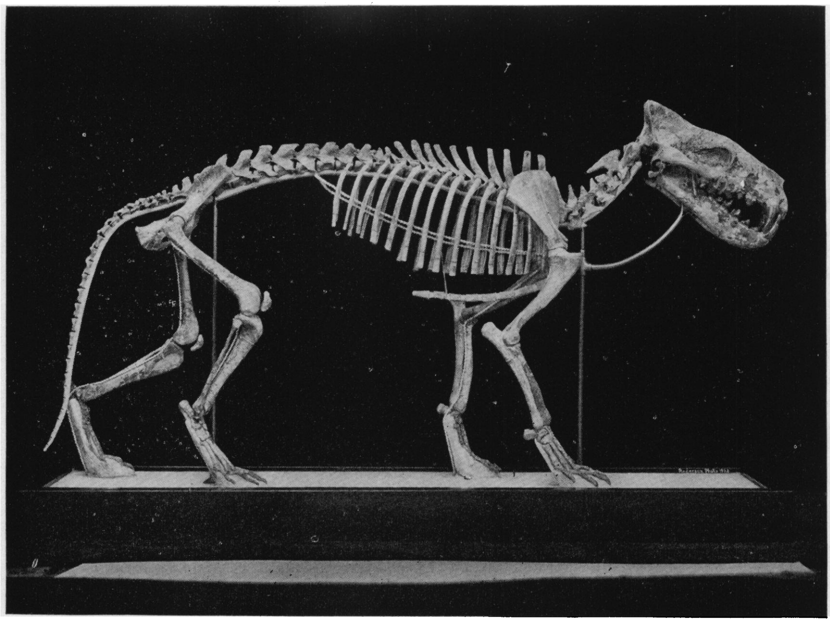
[1] Amer. Naturalist, XLII, 1908, pp. 43–47.

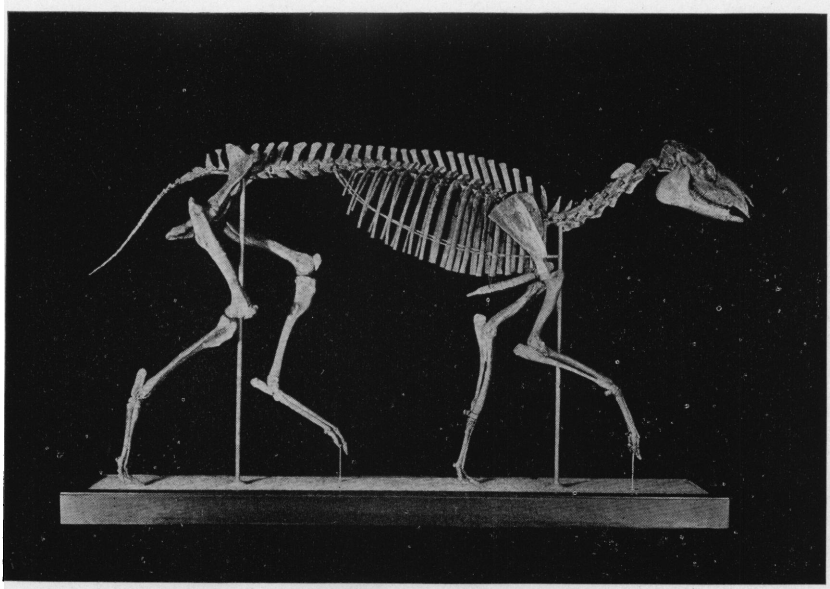
tory we have one in use which weighs eight pounds (about the smallest made). It can be attached to any incandescent light block and bores easily a ¼ inch hole in iron. It is especially advantageous when mounting skeletons in which it often becomes necessary to drill a hole in the iron or in the bone, when in position.

It is understood that the latter tool can only be installed where electricity is available, while any of the other appliances mentioned can be operated by steam-power also.

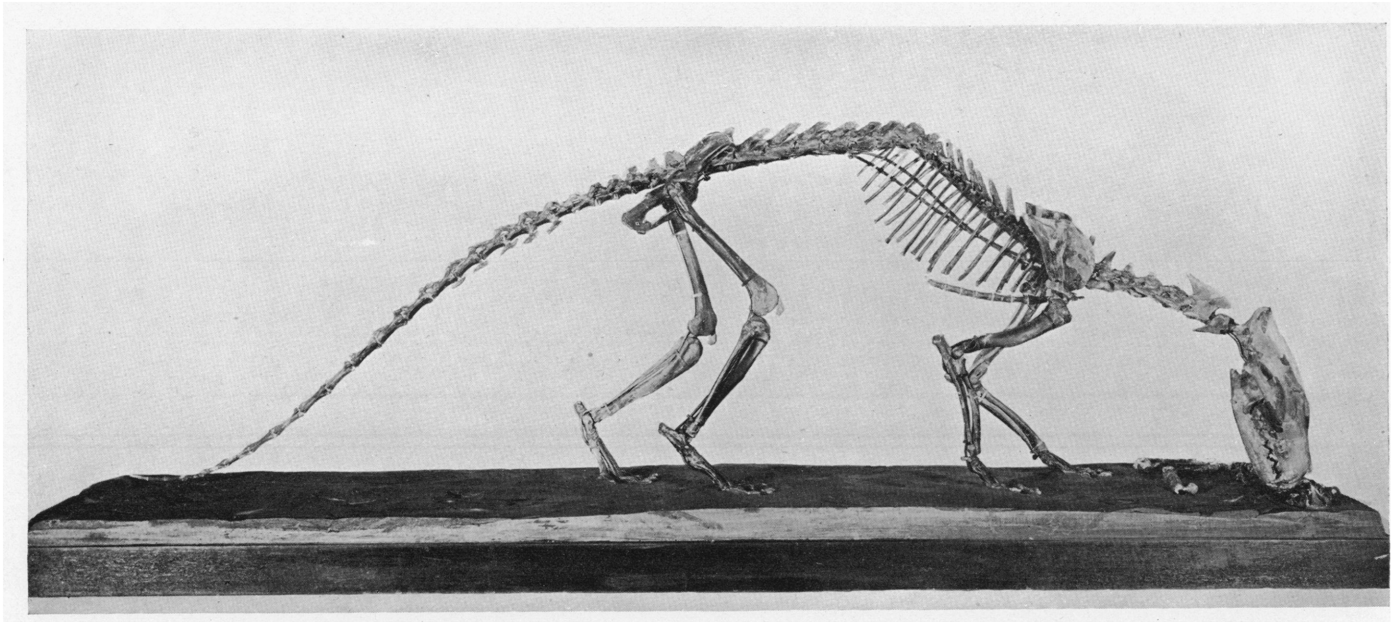
In closing this paper I will say that I have alluded to the most practical methods of preparing, restoring, casting and mounting fossil bones, there are however other ways which are too numerous to mention and which would make this paper too extensive if gone into. A practical palæontologist will overcome difficulties which may occur, by using some ingenuity, since different specimens require different treatment. He must be competent to judge what kind of tools to use for a certain kind of work and how to use them. I therefore say, that a beginner in a palæontological laboratory never ought to be trusted with a delicate and rare specimen. In my experience, I have seen irremediable damage done on account of poor judgment.



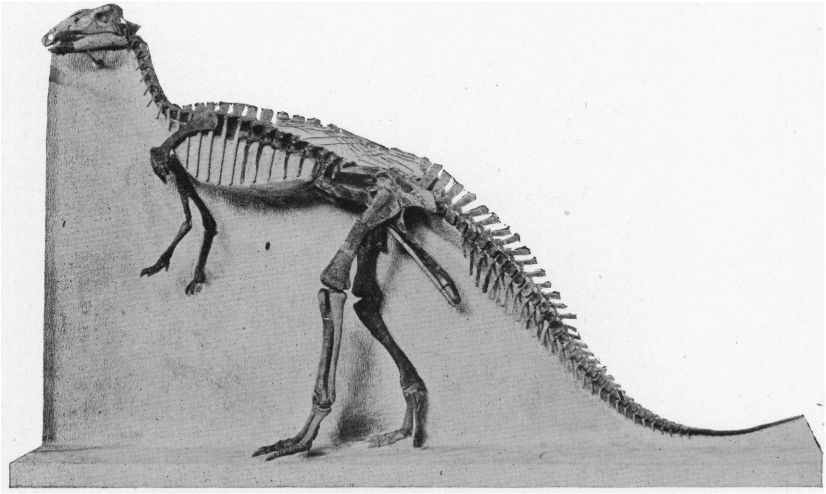
A. *Hyænodon skeleton.* Backbone support of fusible metal, centra of vertebræ free on one side.



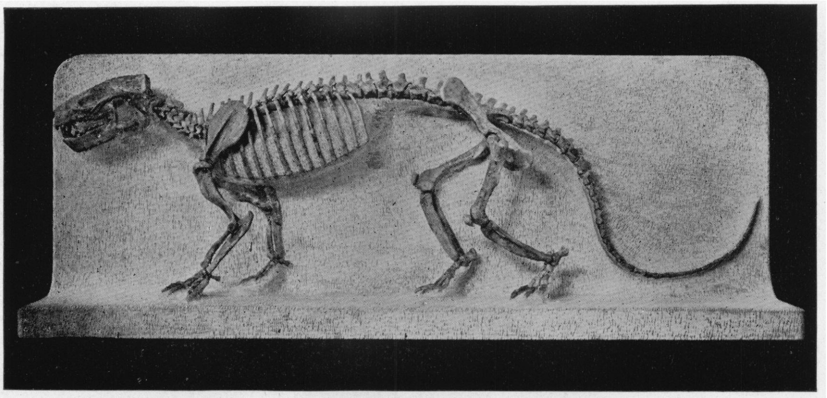
B. *Mesohippus* skeleton. Backbone support running through neural canal, limb supports passing through the bones.



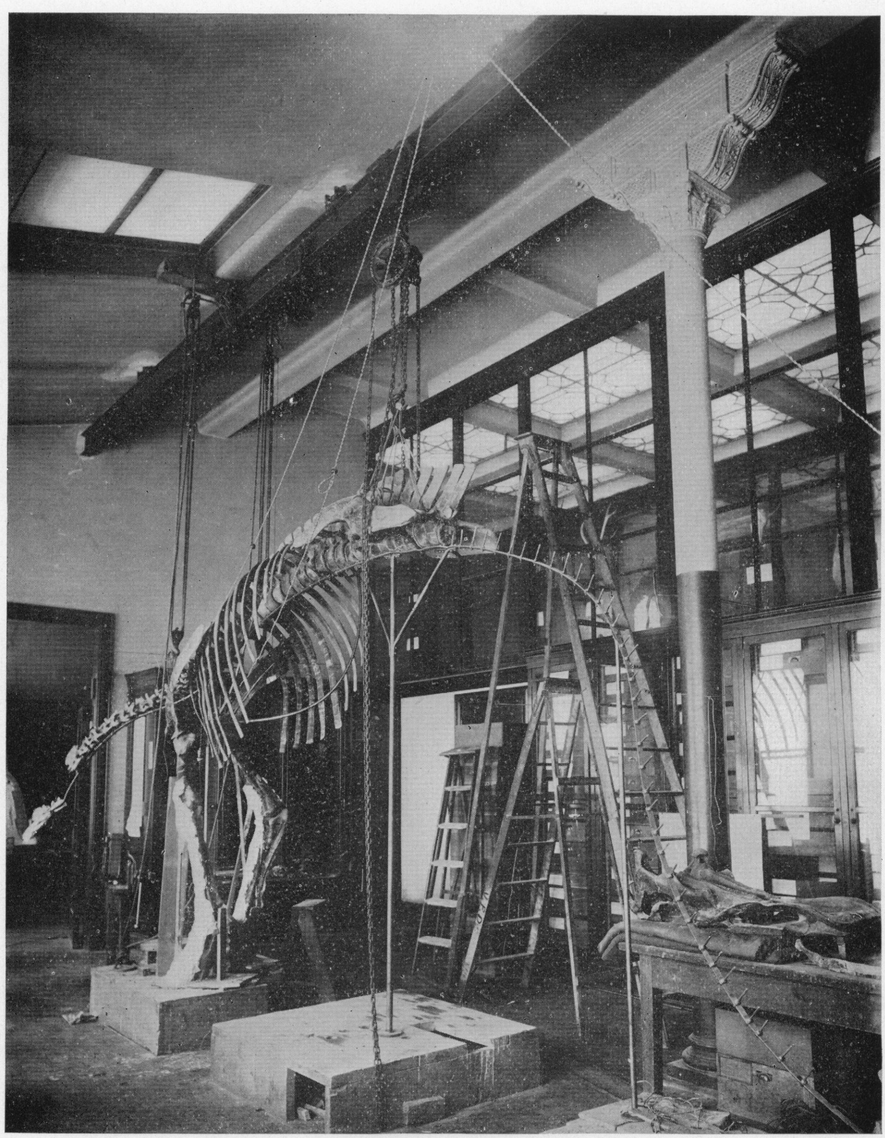
Skeleton of *Tritemnodon*; supported by rods running along the limbs; no uprights.



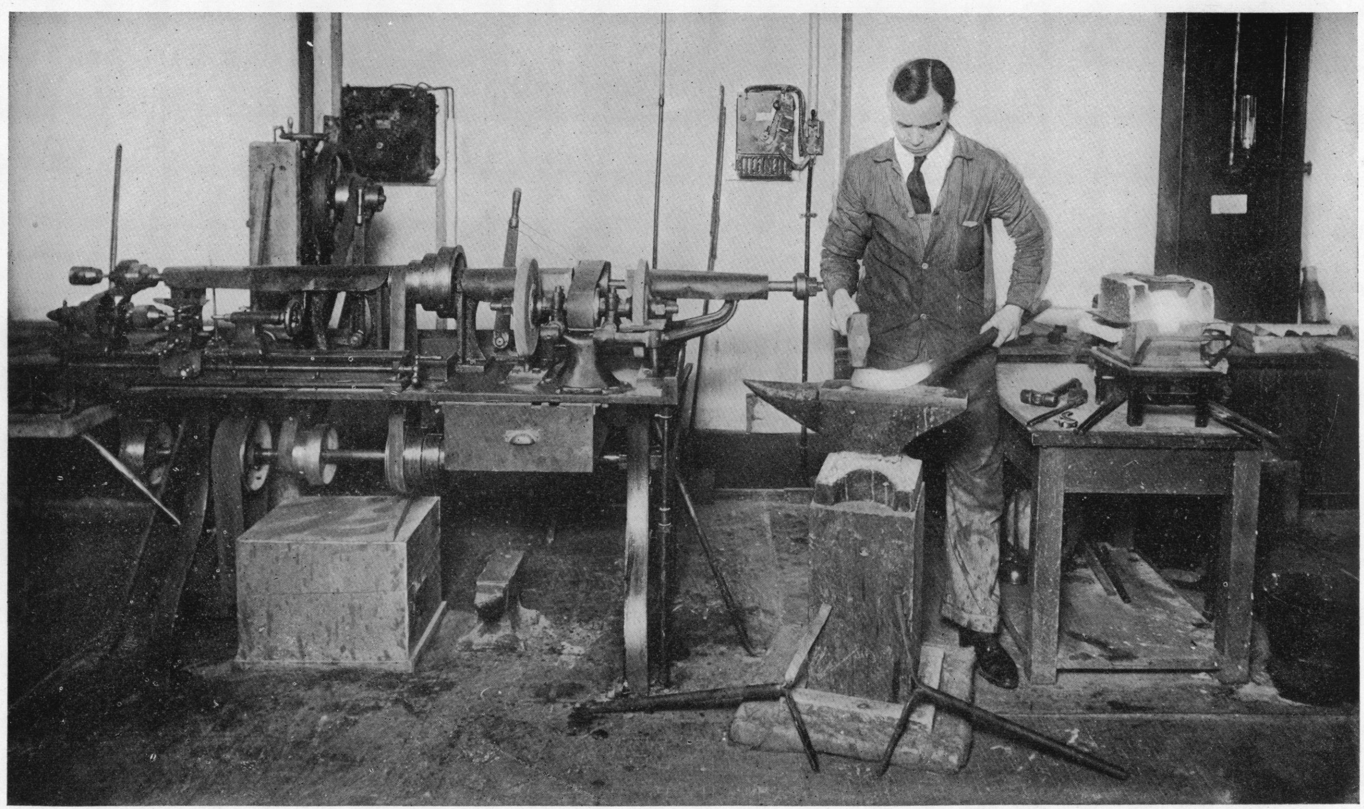
A. Relief mount of *Camptosaurus* skeleton.



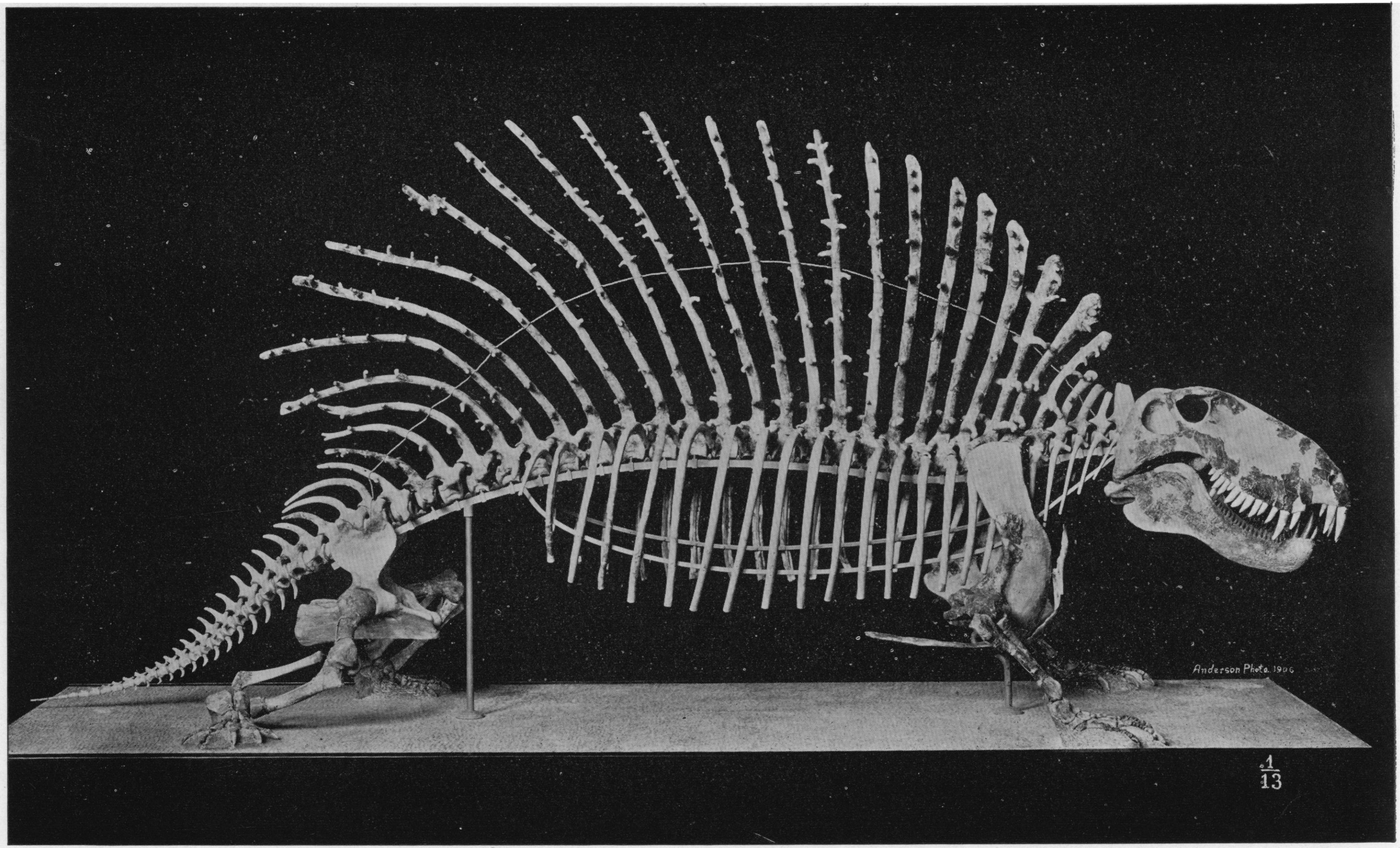
B. Relief mount of *Pantolambda* skeleton.



Trachodon skeleton showing pins for support of vertebræ; suspended from overhead trolley.



Lathe, including appliances for turning, boring, grinding and section-cutting; gas-blast forge and anvil.



Skeleton of *Naosaurus*; all bones bored, with rods inserted.