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CURRENT TECHNIQUES FOR FOSSIL SKELETON MOUNTING

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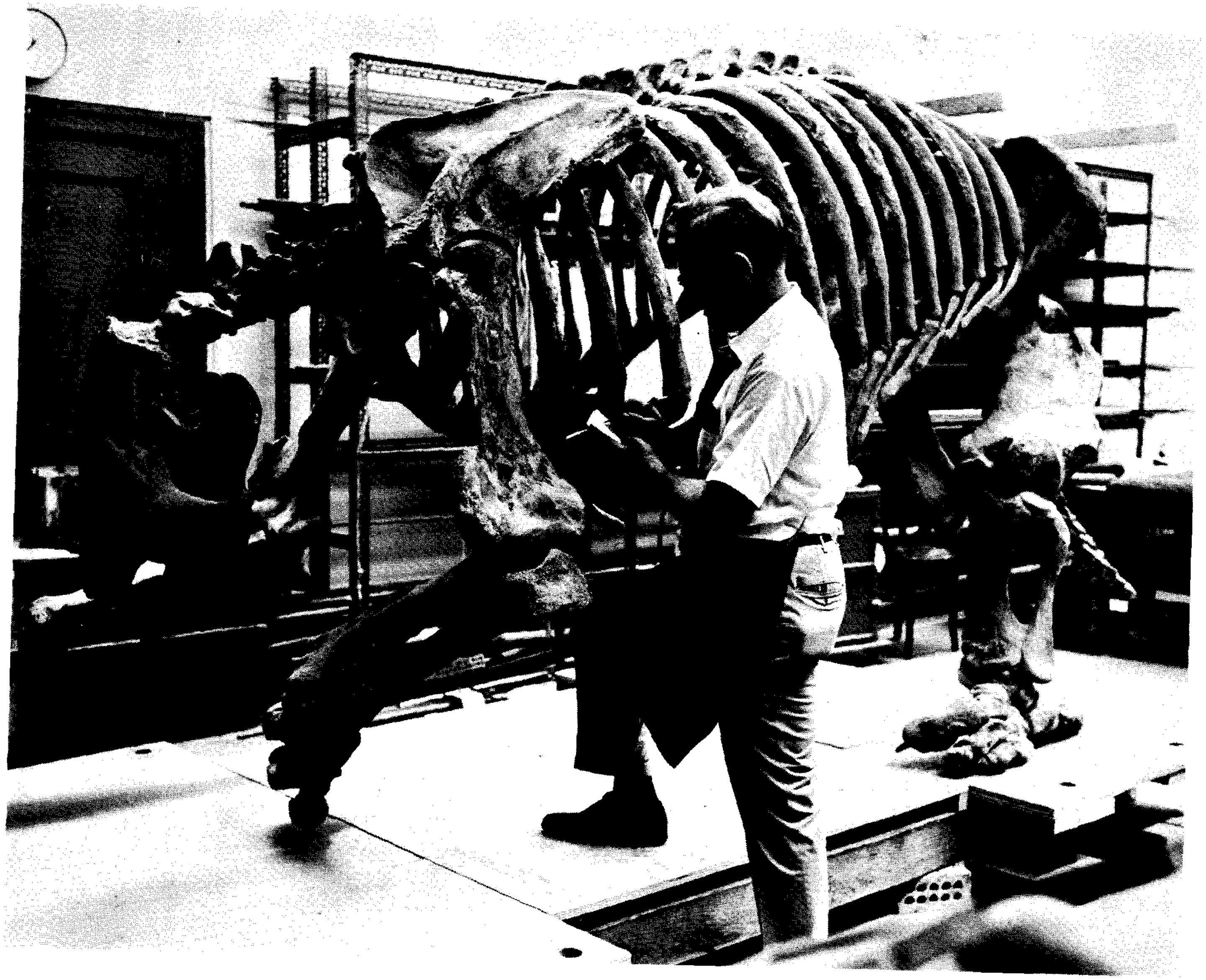
CONTENTS



Mr. Pearce at work on the Ground Sloth display in the National Museum Paleontology Laboratory.

INTRODUCTION

When SLAC received the beautiful castings of the Paleoparadoxia bones that were made for us at the University of California, Department of Paleontology, from the fossil bones discovered here in 1964, it was decided that a permanent standing model should be constructed of them to be kept on display at the Accelerator Center. Simultaneously with the painstaking work of preparing reconstructions of those bones that were missing from the original specimen, I have tried to gather some information on the current methods and techniques being used in the building of mounted fossil skeleton displays. In so doing I have visited paleontology preparation laboratories in several museums and universities, where experts in this field have kindly shown me the details of their methods, equipment and materials, and displays, both completed and under construction. This paper is a compilation of the store of notes and sketches that I made during these instructive visits, and also includes the many suggestions offered as solutions to the special problems presented by the Paleoparadoxia skeleton.

Since our fossil was a large animal, of the approximate size and proportions of a present-day hippopotamus, the construction of the mounting will involve the careful engineering of an adequate steel support system. Although I am not competent myself to do this engineering I can count on all the help I will need from others here at SLAC who are, and I have produced this report primarily for their use. But I also hope that it might be of some help or interest to others outside SLAC, since I have found that almost nothing on this subject is presently available in print.

I have made several visits to the Division of Vertebrate Paleontology at the National Museum of Natural History in Washington, D. C., where Mr. Franklin Pearce showed me all the aspects of the work being done in the preparation labs there, and patiently explained the methods and techniques in use, with suggestions I could apply to Paleoparadoxia. Among many other things I was shown details of the construction of the display of two giant ground-sloth skeletons then nearing completion (see frontispiece), and of a large mammoth mounting being repaired and rebuilt.

At the Los Angeles County Natural History Museum Mr. Leonard Bessom allowed me to watch and sketch the details of all the mounting work then underway in the laboratory, kindly answering my numerous questions, and also adding some helpful ideas that could be used in the Paleoparadoxia mounting. The photograph on page 8 shows the completed skeleton display of the rearing horse that Mr. Bessom was constructing at the time of my visit, details of which I have used by way of illustration a number of times in this report.

Dr. James Madsen of the University of Utah in Salt Lake City guided me through his large laboratory on the university campus where the research and mounting of fossil dinosaurs is the main activity. Dr. Madsen has supervised the construction of a number of impressive Allosaurus skeleton displays, including the one familiar to us in the main hall of the California Academy of Sciences museum in Golden Gate Park, San Francisco. He also showed and explained the design of the support system for his mounting of a specimen of Smilodon, a sabre-tooth cat from the La Brea Tar Pits, that he has presently under construction. Some of the details of this project are described later in this report.

Mr. Lester Kent of the Paleontology Department of the University of California at Berkeley is responsible for the fine casting of the Paleoparadoxia bones, of which we have one complete set. He also has been doing the casting of our oil-clay reconstructions of the missing bones, has instructed me in the techniques of working with the plaster and clay, and has given me several invaluable tips and a great deal of help along the way.

USE OF BEESWAX FOR HARDENING AND STRENGTHENING*

If the actual fossil bone is to be used in the display, it should be treated with something to increase its durability and strength. In some cases the bone may seem very hard and stony, but usually it is somewhat crumbly, particularly on the inside. Fossil displays in older museums have a way of starting to fall apart after many years of standing, as the bone begins to gradually deteriorate. Many preparations are available to paint or spray on the fossil, which do not significantly change its appearance, but in actuality it is found that they do not really penetrate beyond a thin outer layer, even when applied under vacuum. At the National Museum in Washington, D. C., it has been determined that using beeswax for this purpose solves the problem admirably. Bones that have been thoroughly impregnated with beeswax remain natural-looking and maintain their strength indefinitely.

The paleontology laboratory obtains the beeswax from the U. S. General Services Administration, which has it available in bleached or unbleached form. Unbleached is used here because it is a great deal cheaper, and works equally as well.

Various arrangements for "cooking in" the wax are possible, depending upon the size and shape of the pieces being treated. Loose teeth or small bones can be done in a foil pie-pan and heated in a regular oven with the thermostat set at about 180°F. Large or awkwardly shaped pieces can be done in the sand-table, with several spot-light bulbs in small goose-neck table lamps to provide the heat. Line a suitably-shaped depression in the sand with heavy aluminum foil to hold the specimen. If its bottom surface is rough, a piece of plastic sheeting can be put under the bone to protect the foil from tearing. A tent of foil can also be fixed over the specimen and lights, to help hold in the heat. Very large pieces can be done section by seetion, instead of all at once.

Heat some of the beeswax in a bucket or coffee-can to the point at which it starts to flow, about 150° to 160°F. The specimen should also be heated somewhat before the wax is applied, for smoother spreading. Apply the softened wax to the top surface of the bone with a paint brush. The lights should then be placed so that the section being treated will cook at about 180°F. Care must be taken to keep the temperature below 200°F or the bone may start to burn.

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* Information supplied by Frank Pearce, Division of Vertebrate Paleontology, National Museum of Natural History, Washington, D. C.

From time to time, more wax must be applied to the top surface as it is absorbed and melts down into the bone. The process must be continued until wax has penetrated entirely through the specimen and starts to melt out of the underside. Be sure that enough fresh was has been applied so that the upper portion has not become drained of wax. If the heat is left on too long, all the wax can be melted out of the specimen again. If the fossil is very thick the wax can be applied until it seems to be more than halfway through, then the piece can be turned upside down, and the treatment repeated; see Figure 1.

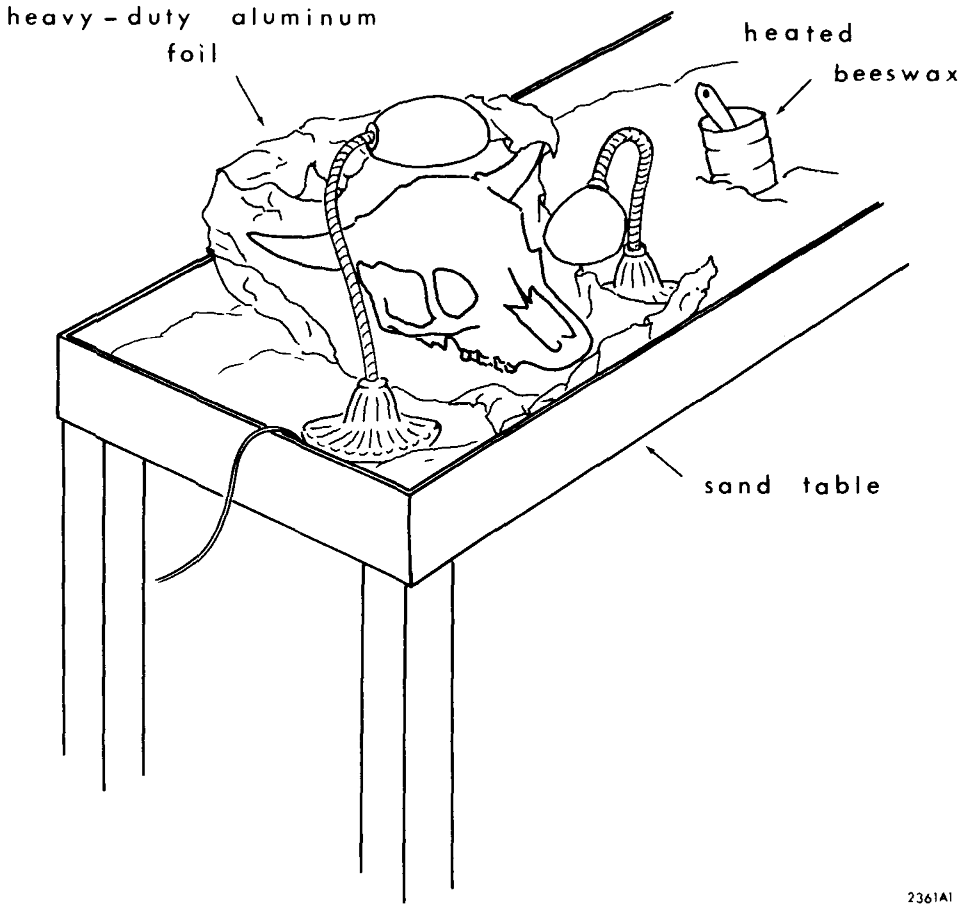


Figure 1. Bison skull being treated with beeswax.

The cooking-in of the wax may take perhaps five to twelve hours depending upon the thickness to be penetrated. The secret is that the entire thickness must attain a high enough temperature to permit the wax to melt through it. Do not try to rush the job by giving more heat at the surface. To prevent the bone from burning, heat must be kept below 200°F.

When cool, the excess beeswax can be saved from the bottom of the foil pan, and excessive coating and drips can be scraped away from the specimen with a paring or pocket knife. Wide cracks or broken out places can be concealed by trimming the wax surface filling the break, so that a flush patch is created. Then broken bits and chips of the fossil material can be ground to a powder and rubbed into the surface of the wax patch until the patch is undetectable.

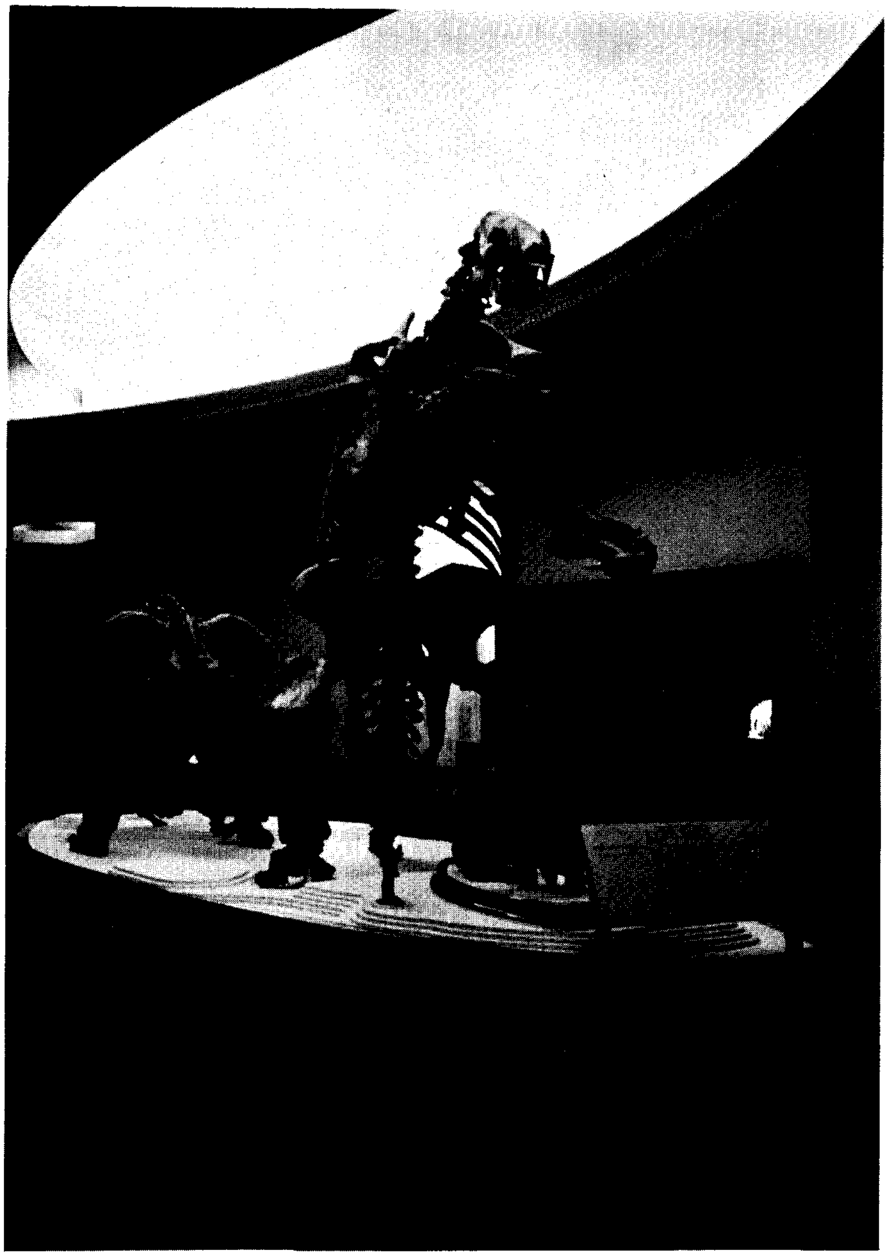
In the laboratory I saw three specimens of fossil peccaries being prepared for a display. The fossils were to appear just as they had been found in the matrix, a soft loess of light dun color. The skeletons had been found all in a line, the most complete one first. They will be placed on the floor of the display in the same order. Each skeleton had been brought to the laboratory in a plaster and burlap field-jacket still in the slab of the surrounding matrix and only partially prepared to disclose the extent and position of the bones.

The beeswax treatment was applied to each slab on the upper surfaces, and allowed to penetrate both bone and matrix as much as possible. Then further cleaning and preparing was done, until the bones were uncovered to most of their depth, but still held in the matrix. In this way broken parts would not fall out and become lost, and missing parts did not need to be reconstructed. Then the finished slabs were turned over and the underside trimmed evenly with a saw to enable them to lie flat. Each was then mounted on a wooden base of suitable size. Softened beeswax was worked in between the edges of the matrix and the wood to make a flush, smooth joint. When cool, the wax was carved with chisel marks, cracks, etc., to match those in the matrix. Then extra chunks of the loess matrix were ground to powder and worked into the exposed beeswax surfaces and over the entire matrix surface to give an even and natural color to the whole piece. One of the slabs had almost a third portion cracked apart from the rest, but the beeswax impregnation held the section in the proper place and filled the crack entirely. When completed, the peccaries will make a very attractive display.

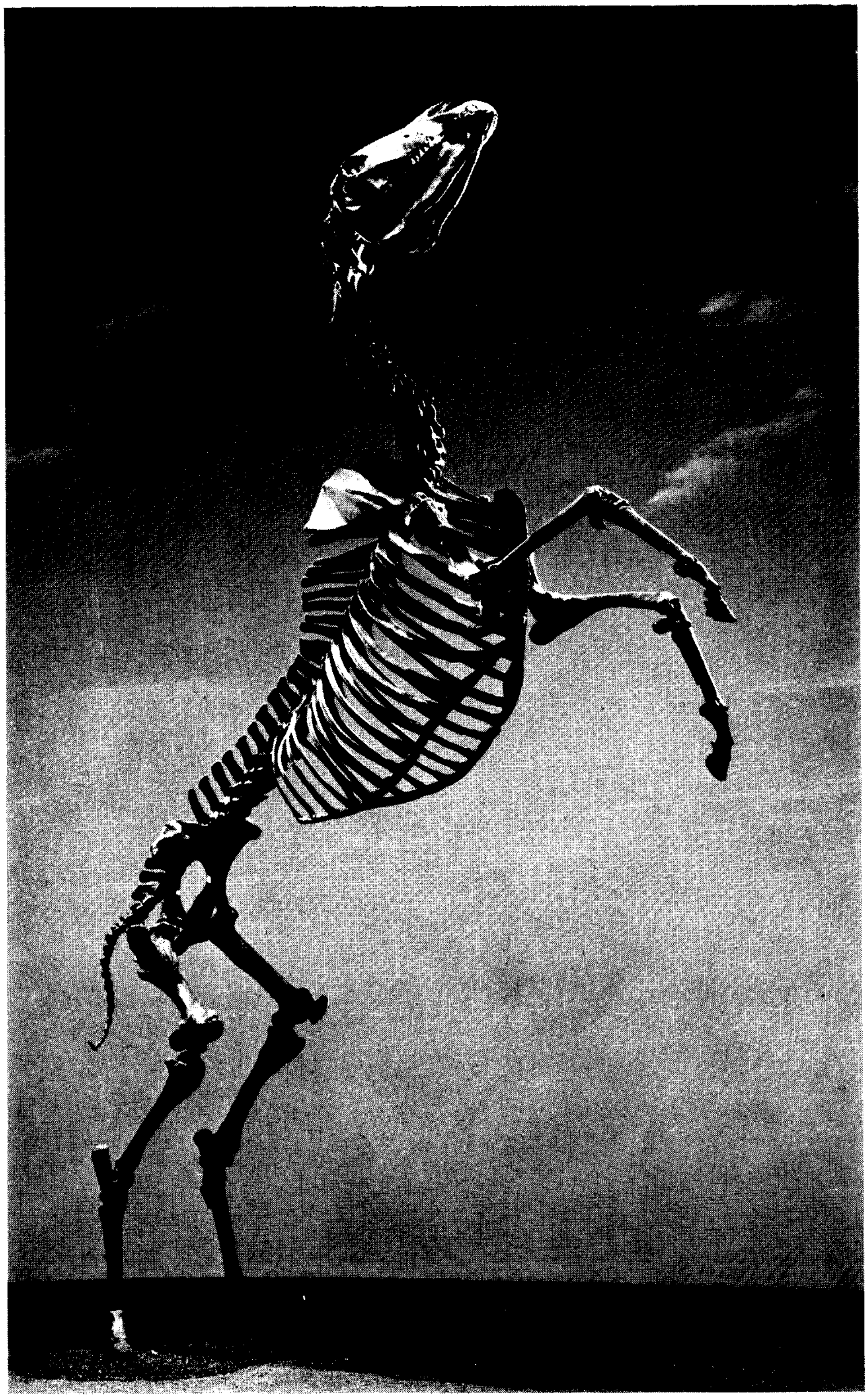
Mr. Pearce also described the way a pair of 6 to 7 foot mammoth tusks were successfully preserved by this method. The tusks arrived at the laboratory in field jackets of plaster and burlap. The insides were very crumbly and the thin outer coating had adhered in places to the newspaper wrapping under the jacket, so that it would not survive the removal of the jacket in the normal way. For the beeswax treatment, the jacket-covered tusks were laid in the sand table. Only a short section was treated at one time. First the plaster jacket was loosely wrapped in a piece of plastic sheeting, and then in foil, leaving the top open, and the section given a preliminary heating. Hot wax was applied on top of the plaster. As the wax became absorbed, more was applied until it had penetrated right through to the underside of the casing. Each treated section was arranged to somewhat overlap the previous one. Care had to be taken not to melt the wax out of the completed section while cooking-in its neighbor. This was accomplished by adjusting the position of the lamps meticulously. To make sure that all parts of the tusks were equally penetrated by wax, including the field-jackets, they were turned over in the sand table and treated again on the other side. Then all the excess beeswax was scraped off the plaster jackets and the plastic sheeting.

To now remove the field-jackets, the plaster was slightly warmed to soften the wax in it. With a sharp knife, the jacket was carefully cut in strips and peeled off while still warm. Then, again with a slight heating, the newspaper wrapping that had been applied under the field jackets could be carefully scraped and peeled off. The delicate outer surface of the tusks was entirely prevented from flaking off, and completely preserved by this method. About 120 pounds of beeswax were used in each tusk.

All fossil bones and teeth can be preserved in this way. If the specimen to be treated should not be completely dried out, that is, if it should still contain some water, it is not necessary to wait until all dampness has dried away. The heat of the impregnation process seems to evaporate out the water as the molten beeswax is absorbed, giving exactly the same result as if the material had been dry.



Completed Giant Ground Sloth display.



Rearing Horse skeleton from the La Brea Tar Pits.

JIGS FOR DETERMINING THE POSITION
OF THE STANDING MODEL*

Before a standing model can be permanently mounted, its final position must be determined, and a steel framework must be engineered of the proper shape and size to support all the bones. The newest and by far the best looking mounts are now assembled so that the support system is almost entirely concealed. Before beginning to make the supporting framework, the final position of the skeleton must be decided, for the permanent support will not be adjustable. Therefore it is wise to have a temporary support system which can clamp each bone tightly, but at the same time allow sufficient movement of each piece so that various stances may be tried.

First one needs to build a strong wooden base large enough to hold the display, which can be drilled into as needed. It should not be elegant for it will not be part of the permanent display. A large, flat wooden box, six to ten inches thick, well reinforced with struts and floored with planks on both top and bottom should serve well; see Figure 2.

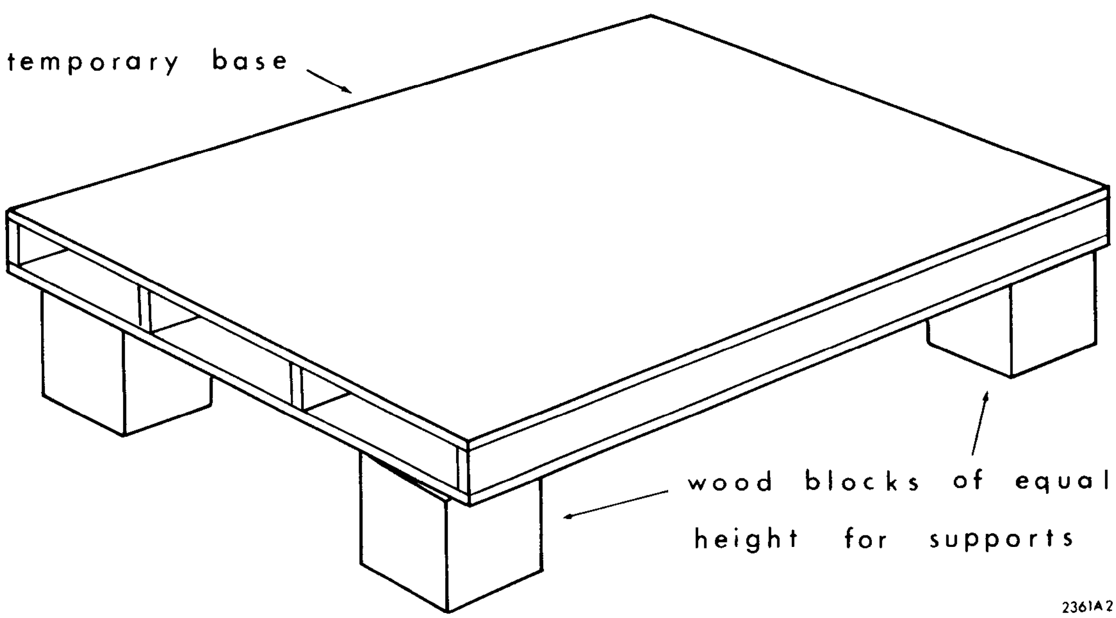


Figure 2. Temporary wood base for the mock-up display.

* Information supplied by Frank Pierce, Division of Vertebrate Paleontology, National Museum of Natural History, Washington, D. C.

Each large bone will need a jointed jig made from a set of three pipes. For Paleoparadoxia various lengths of one-inch water pipe will be suitable. The top end of each pipe should be fitted with a T-joint that is of the right size to allow another one-inch pipe to be inserted into it, $1\frac{1}{4}$" x $1\frac{1}{4}$" x 1". If preferred, T-joints of 1" x 1" x 1" size can be used by machining away the threads on the inside of the two arms, so that the one-inch pipe will slide in. This method gives a tighter fit.

Each T-joint must be welded to its pipe to prevent it from turning when much weight is on it, and it must be provided with two set-screws for clamping the inserted pipe in the desired position. One of each set of three pipes, that which is intended to be attached to the base, should be threaded 10 or 12 inches at the bottom end and two opposing flanges provided for clamping the pipe to the wooden base. At the spot where it is desired to place the jig, a hole should be drilled through top and bottom of the base of the correct diameter to fit the pipe. Then the two flanges can be tightened down onto the base and the top one secured by large wood screws; see Figure 3.

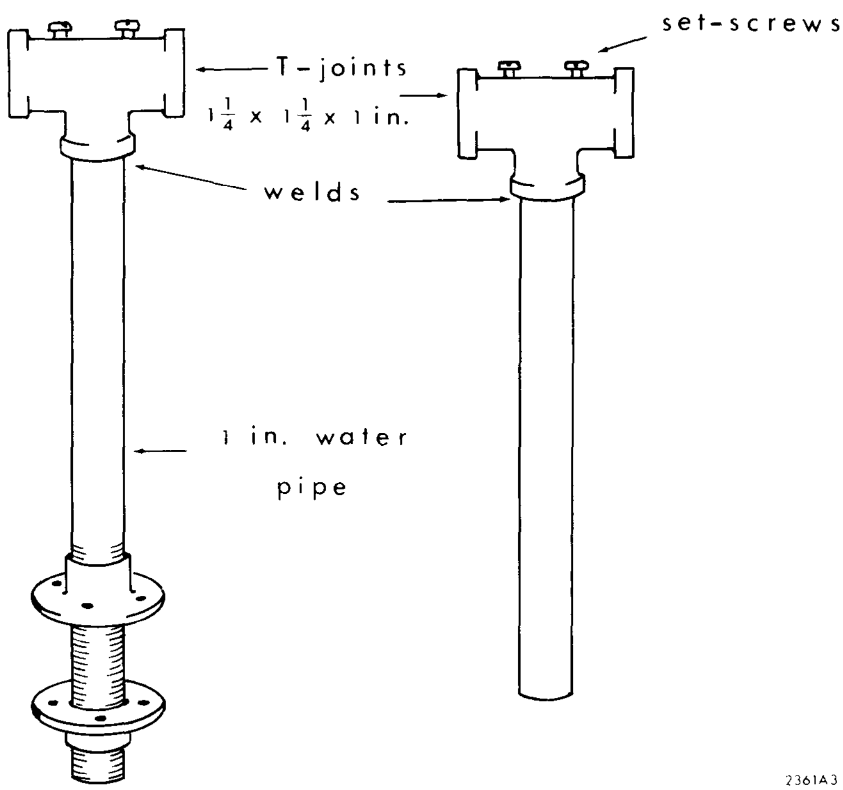


Figure 3. Diagram of jointed-jigs for clamping bones in the mock-up display.

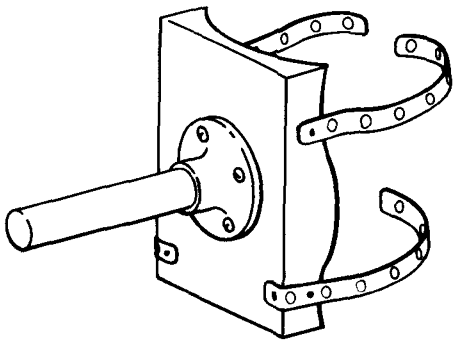


Figure 4. One type of bone clamp for the temporary display.

Now a special clamp for each large bone must be manufactured. A sturdy piece of wooden board can be chosen and cut to suitable dimensions for the bone it is to hold. Some whittling and shaping with a rasp on one side of the board may be necessary for a good fit. Strap iron is then attached at each side, as shown in Figure 4, which will be bent around the bone to clamp it tightly to the board.

Now a shorter length of one-inch pipe must be affixed to the back of the board perpendicularly. This pipe is to be clamped into the T-joint of the third section of the pipe jig. When the clamp and three pipes are assembled, the resulting jointed device allows each bone to be placed in any position and angle and clamped there; see Figure 5.

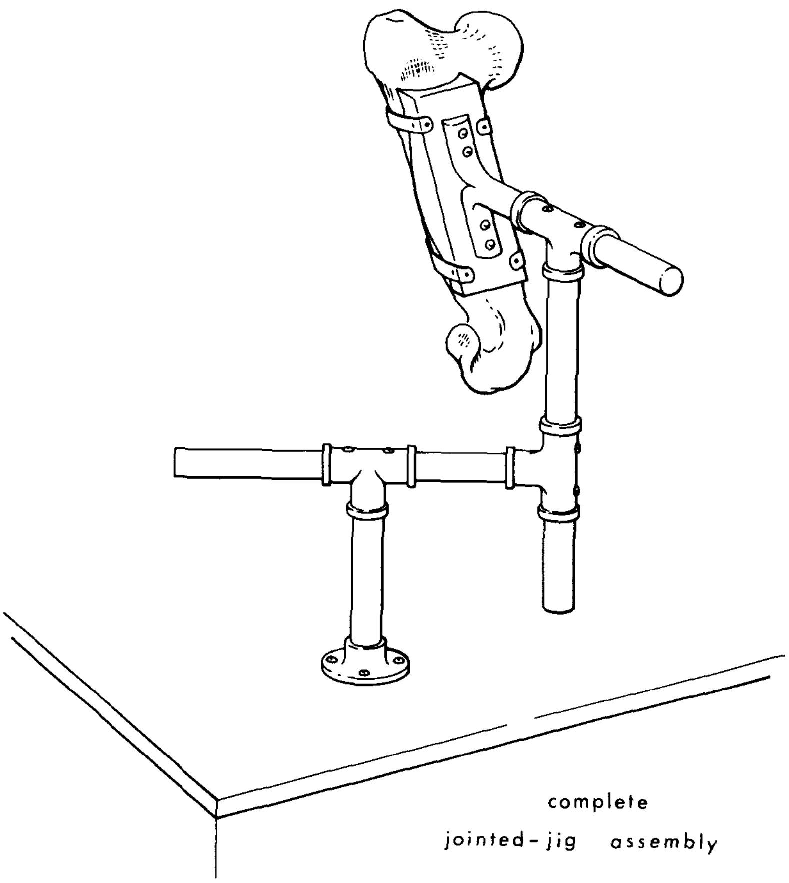


Figure 5. Complete jointed-jig assembly.

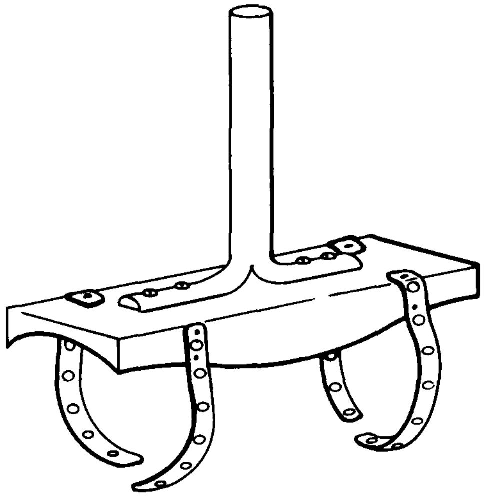


Figure 6. Another style of bone clamp.

If the clamp being made is for a large bone, so that the board is wide enough to permit it, the piece of pipe can be attached to the back with a regular pipe flange and wood screws, as shown in Figure 4. If the board is too narrow for a flange, a split steel rod of the same diameter as the pipes can be used instead. Slit one end of the rod down the center for a length of two or three inches. Now bend each half up by 90°. Drill two holes in each leg, and fasten it to the board with four wood screws; see Figure 6.

It has also been further suggested by Mr. Pearce that greater flexibility is obtained by making the base pipe from a telescoping set of two pipes, as described below for the backbones, and shown in Figure 7. In some instances it might be desirable to use a fourth section of pipe with T-joint in the jig arrangement, to give more degrees of freedom.

The vertebrae can be held, three or four at a time, in a sort of wooden cradle that can be tilted through about 90° of angle, as illustrated in Figure 7. The cradle can be supported on a telescoping pipe with set screws for adjusting the height, and attached to the wood base by two flanges, in the same way as depicted for the jointed jigs. A sufficient number of these devices will be needed to support the entire length of the backbone and neck in the temporary display. A similar but larger sized device can be made to hold the skull and jaws.

After determining the general positions of the limb bones, head and spine, the foot bones will have to be positioned. These can be supported above the base on small blocks of wood, bits of clay, and other handy objects. It is important to have all the bones included in the final set up to be sure that everything will fit as planned. The time to make even the finest adjustment to the final position is now, while everything can still be changed. When the final position is determined tighten everything on the temporary jig so that nothing can move while the permanent support system is being manufactured.

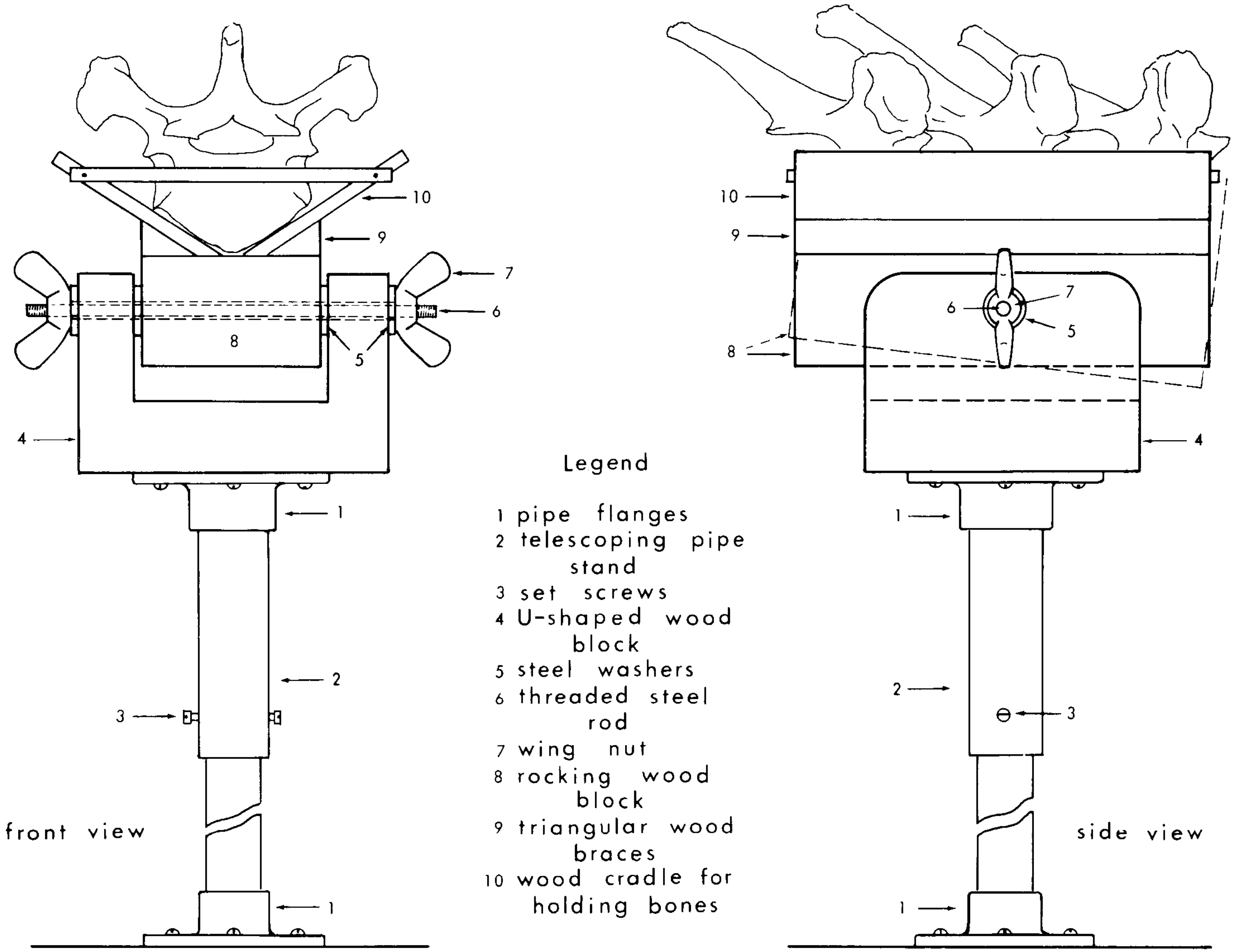


Figure 7. Tilting cradle for holding vertebrae in the mock-up display.

THE PERMANENT SUPPORT SYSTEM

The most important rule to remember when engineering the steel framework for the model is: NO bone must be made to support more than its own weight. ALL the bones must be suspended individually to the support system. Therefore the bones should each be pinned separately to the support, with a narrow space between each one, as would be filled in life with cartilage.

The materials used to make the support system vary, according to the size and weight of the skeleton, from thin steel rods and wire, to one-inch or more solid, cold-rolled steel rod. Three-quarter inch or one-inch rod will probably be suitable for our paleoparadoxia but to be sure that the complete support system will be adequate the entire set of plaster cast bones should be weighed. We need not expect terrific problems of weight of the individual pieces, since we are using plaster castings which are comparatively much lighter than fossilized bone. Smaller bones can be pinned to the structure with one-quarter inch steel rod.

The plaster can be drilled with core-type masonry drills, or steel twist drill bits in some cases. Mistakes can be filled with fresh plaster, allowed to set to harden, and then be drilled again. Many of the suggestions on the following pages require cutting slots or sections into the surface of the plaster pieces for the insertion of wires or other apparatus. In all these cases, the cut-away portions will have to be filled with fresh plaster and the outside surfaces restored to their original appearance after the installation of the devices. If a large area is to be cut away it may be possible to use a thin rotary saw blade to do the cutting and preserve most of the outside surface of the section, which can then be replaced when the patching is done. Details of techniques to use in working with the plaster are discussed in a later section.

As already mentioned it will frequently be suggested to pin two or more bones together with short sections of steel rods. To accomplish this, holes of the proper I.D. for a good fit will need to be drilled into both plaster pieces for the insertion of the rod, and the steel pins secured in them with wet plaster, glue, or epoxy. Sections of pipe and other fixtures can also be installed in this way.

In most cases it would be preferable to engineer the support system so that it will not be impossible to take apart and reassemble the skeleton in the future, either piece by piece or in unit sections, for moving or repairs.

Spinal Support

The primary member of the supporting framework is the spine. A cold-rolled steel rod, of perhaps 3/4-inch diameter, must be given the desired curvatures for the spinal column and neck, extending sufficiently at both ends to accommodate attachments for the skull and the pelvis and tail. It should be possible to mount the vertebrae on this rod loosely through the vertebral foramina. Due to some variations in the vertebrae, it may be necessary to enlarge the foramen in some of the bones, or perhaps the spinal rod could be manufactured of two smaller rods welded together to give an oval cross-section, which might fit the vertebral foramina better, as was done in the mounting of the La Brea horse. To prevent the weight of the bones from hanging on the rod, a smaller diameter rod, perhaps of 1/4-inch stock, and similarly curved, must be inserted through the bodies of all the vertebrae. The holes for this rod should be drilled carefully so that the smaller rod will be an equal distance below the main rod for the entire length of the back. Then a small L-shaped spacing device of strip steel must be inserted between every sixth, or so, vertebra for the purpose of clamping the smaller rod to the larger one. Of course, each spacer must be the exact length equal to the desired distance between the two rods. Steel hose clamps, or nylon cable ties can be used to hold the spacers to the main rod. A little dark paint applied to these mechanisms is enough to prevent them from being visible in the finished mount. The spacers could be made of 1/2 or 3/4-inch wide strap steel which has a 1/4-inch hole drilled at the lower end for the small rod. See Figure 8 for diagrams of the complete fixture.

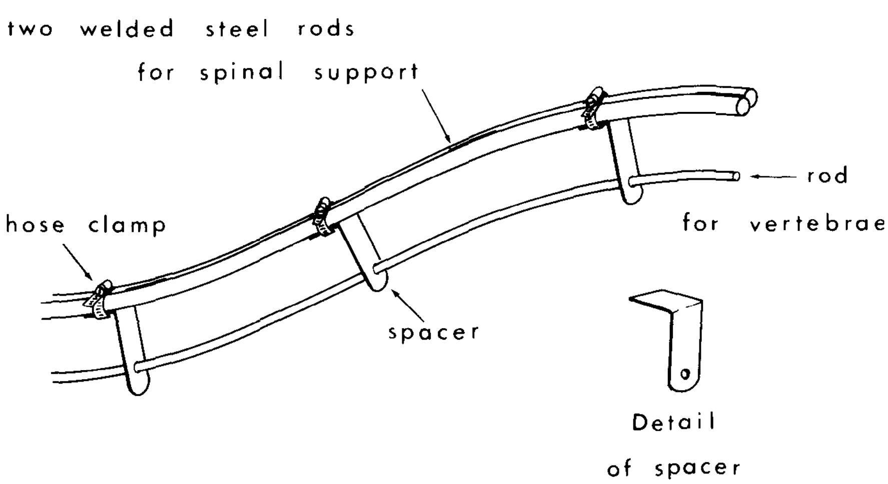


Figure 8. Central spinal support apparatus.

Dr. Madsen of the University of Utah suggested that the lower rod through the center of the vertebrate and all the spacers and clamps could be eliminated by orienting the double welded spinal support rod vertically instead of horizontally. He suggested that black pipe could be used instead of solid steel rod, to reduce the total weight. Three-eighth inch I.D. pipe could be used to pass through the vertebral foramina, welded to 1/2 or 3/4 inch I.D. pipe which would pass through holes drilled through the centrum of each vertebra. This method is illustrated in Figure 9. If it seems necessary to prevent the bones from rocking on the support rods plaster can be worked in around the pipes in the final installation process.

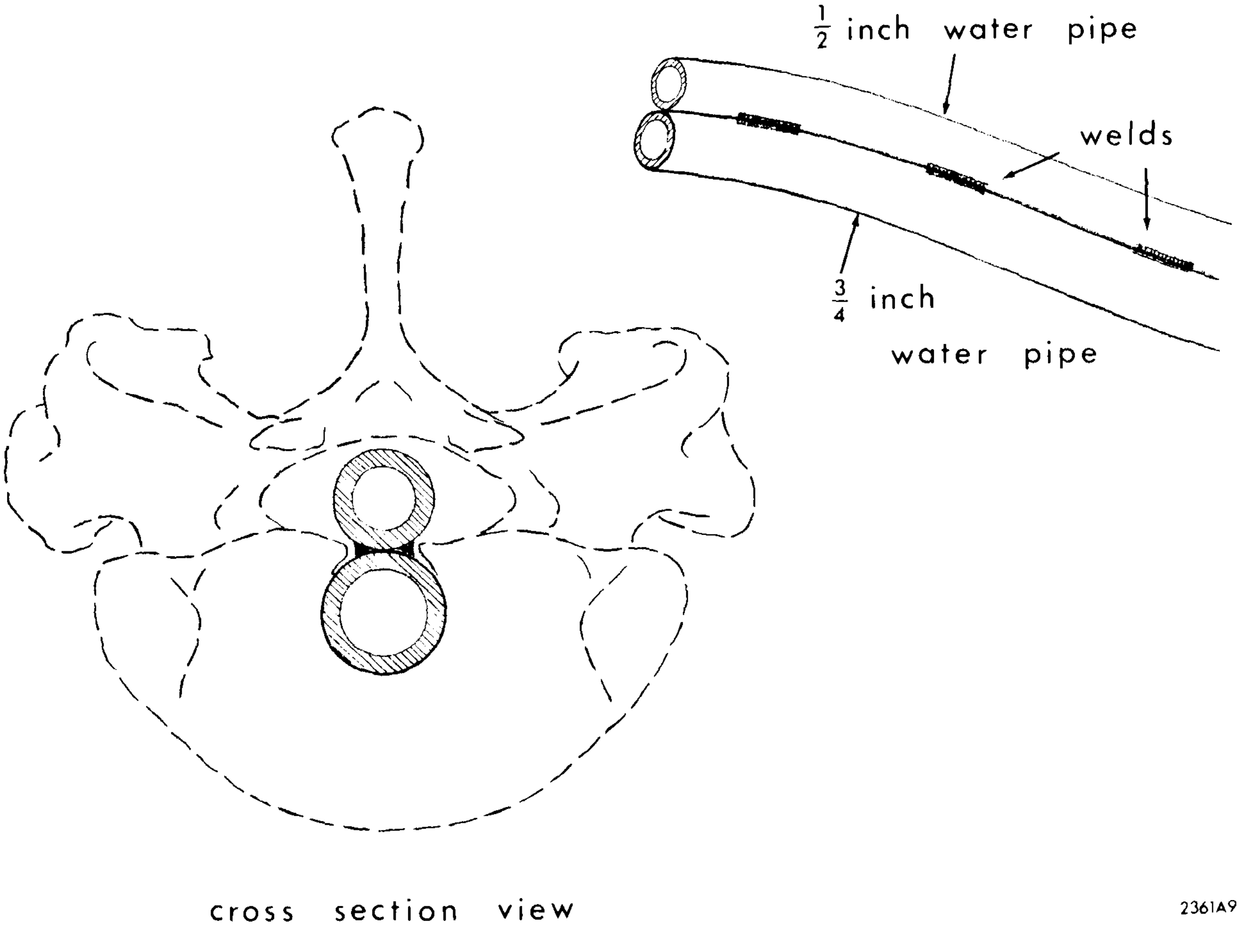


Figure 9. Another suggestion for the central spinal support rod.

Rib Cage

In past times it was customary to make a large bow-shaped steel framework for supporting the ribs of the mounted skeleton. Each rib was bolted to this frame, and the frame itself and all the bolts were quite visible. Nowadays this steel ring is usually eliminated by employing other devices. One way to give the rib-cage rigidity of its own is to recreate the cartilage attachments (costal cartilages) which in life extend from the end of each rib to the sternum or breast bones. These can be made of a rigid enough wire or steel rod to give sufficient strength to the rib-cage that it will support itself from collapse.

If the skeleton to be mounted is small and the individual parts not heavy, it might be satisfactory to attach this completed rib-cage assembly to the backbone by pinning the rib-heads directly to the rib-facets in the vertebrae with bent pegs and glue. But for a large animal such as paleoparadoxia it would be wiser to obey the rule mentioned in the beginning of this section, that no bone should be expected to hold more than its own weight in the finished mounting. Frank Pearce gave me some ideas of how this could be accomplished, which I shall describe below.

Since paleoparadoxia's ribs are made of unreinforced plaster, they are brittle and not too strong. To remedy this we can insert a strip of strap steel, perhaps 3/8-inch by 1/16-inch in cross-section, down the entire length of each rib, and extending by several inches from each end of it, see Figure 11a. This will require a 3/8-inch slot about half inch deep made with a rotary wire brush in a small electric hand drill as shown in Figure 10.

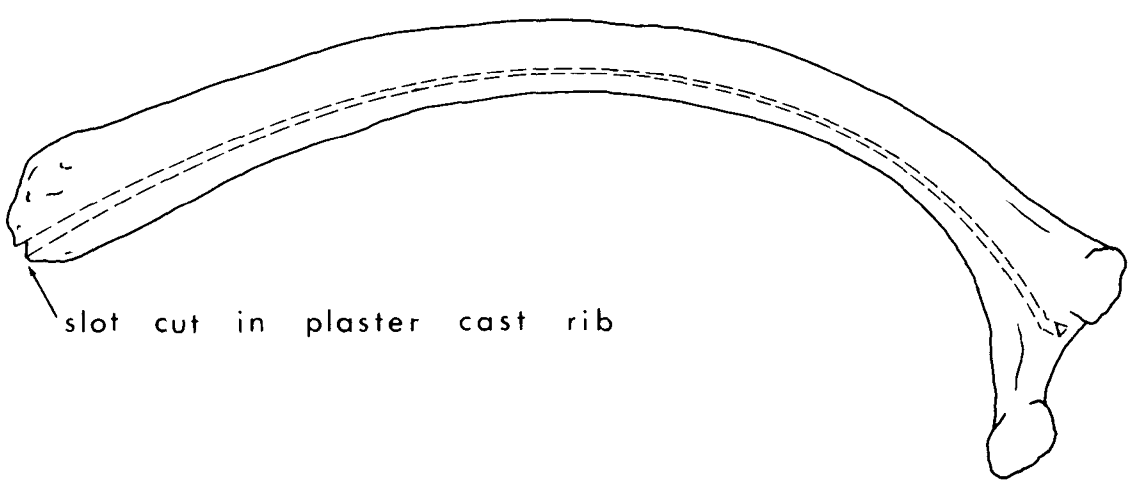


Figure 10. Rib bone slotted for insertion of reinforcing.

Each slot must be carefully cut down the inside surface, that is the concave side, of each rib, and after the insertion of the steel strap bent to the proper curvature, the slot must be plastered over and patched to its original appearance.

Mr. Bessom suggested that fiberglass roving could be used inside the ribs in place of strap steel. On the day before the insertion of the roving into the slotted ribs the bottoms of the slots should be painted with uncatalyzed resin, which will partly soak into the plaster, thereby increasing the bond and also the strength of the ribs. An eye of wire with a crimped stem (Figure 11b) should be made for each end of each rib. When the roving, thoroughly saturated with catalyzed resin, is placed in the slot the stem of one wire loop must be worked into the wet roving at each end for the necessary rib attachments. After the fiberglass hardens the slots should be plastered over and the surface restored. Figure 11b illustrates the rib finished in this way.

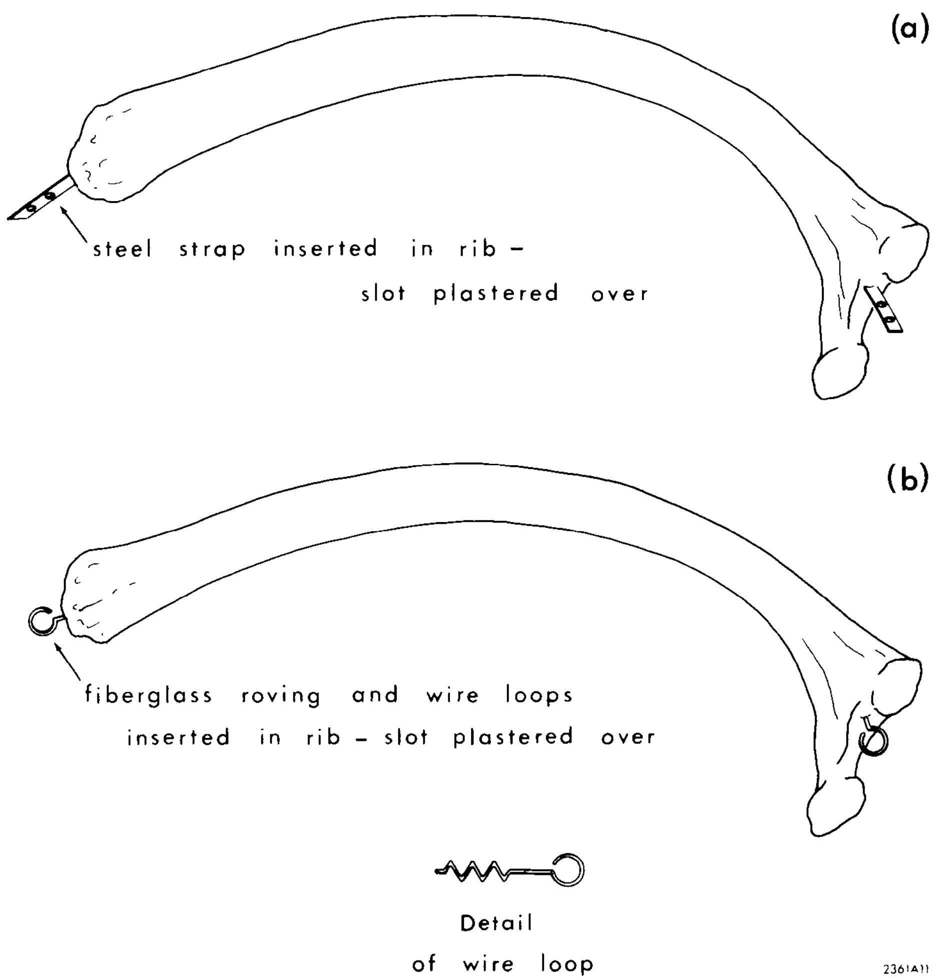


Figure 11. (a) (b) Two possible methods for the reinforcement of the ribs.

Although our ribs must seem to attach to the thoracic vertebrae the actual weight of the rib-cage must be taken by the central spinal support. The suggested methods for accomplishing this are illustrated in Figure 12. For each pair of ribs a little steel semicircular hanger with extended ears should be manufactured. These are to be placed over the spinal support between each backbone so that the ears extend to the rib-head facets on the vertebrae. Each pair of ribs is mounted to its hanger by drilling two matching holes in each of the hanger ears and the straps extending from each rib-head, and assembling all together with small nuts and bolts, as shown in Figure 12a. The attachments can be bent slightly to adjust the rib-heads to fit the vertebral facets properly, when the mounting is completed.

In many cases it would be easier to mount the ribs to the spine with wire loops that fit around the spinal support as shown in Figure 12b. Wires are then threaded through these and the eyes at the heads of the ribs, and twisted to tighten. To disassemble the rib cage from the mount one merely cuts these twisted wires.

Paleoparadoxia seems to have a very singular sternum composed of two rows of flat bony plates instead of the usual single line of rod-like bones. These separate sternum plates must be assembled into a single unit, each piece being pinned to each of its neighbors by two or three small rods. The sternum bones will be placed at a natural distance apart from each other, leaving room for the simulated cartilage to be applied between them; see Figure 13. This is done with a home-made preparation, called "guck" by the preparators at the National Museum, which they mix from ground asbestos and Butvar, a polyvinyl acetate resin. This compound can be prepared as needed, and kept in tightly closed cans. It can be readily worked, shaped and manipulated, having the consistency of putty. It hardens upon drying but still can be carved with a knife, filed, or sandpapered. It can be painted afterwards, or pigments can be added to the original mixture. I shall give the complete recipe and directions for making "guck" at the end of this section.

A number of attachments of strap steel, wire, or steel rod must be firmly inserted into the outer edges of the sternum assembly for the fastening of the sternal pairs of ribs. There may be four or five pairs of these, the first pair attaching to the sternum at the forward end and the rest at the two sides. The

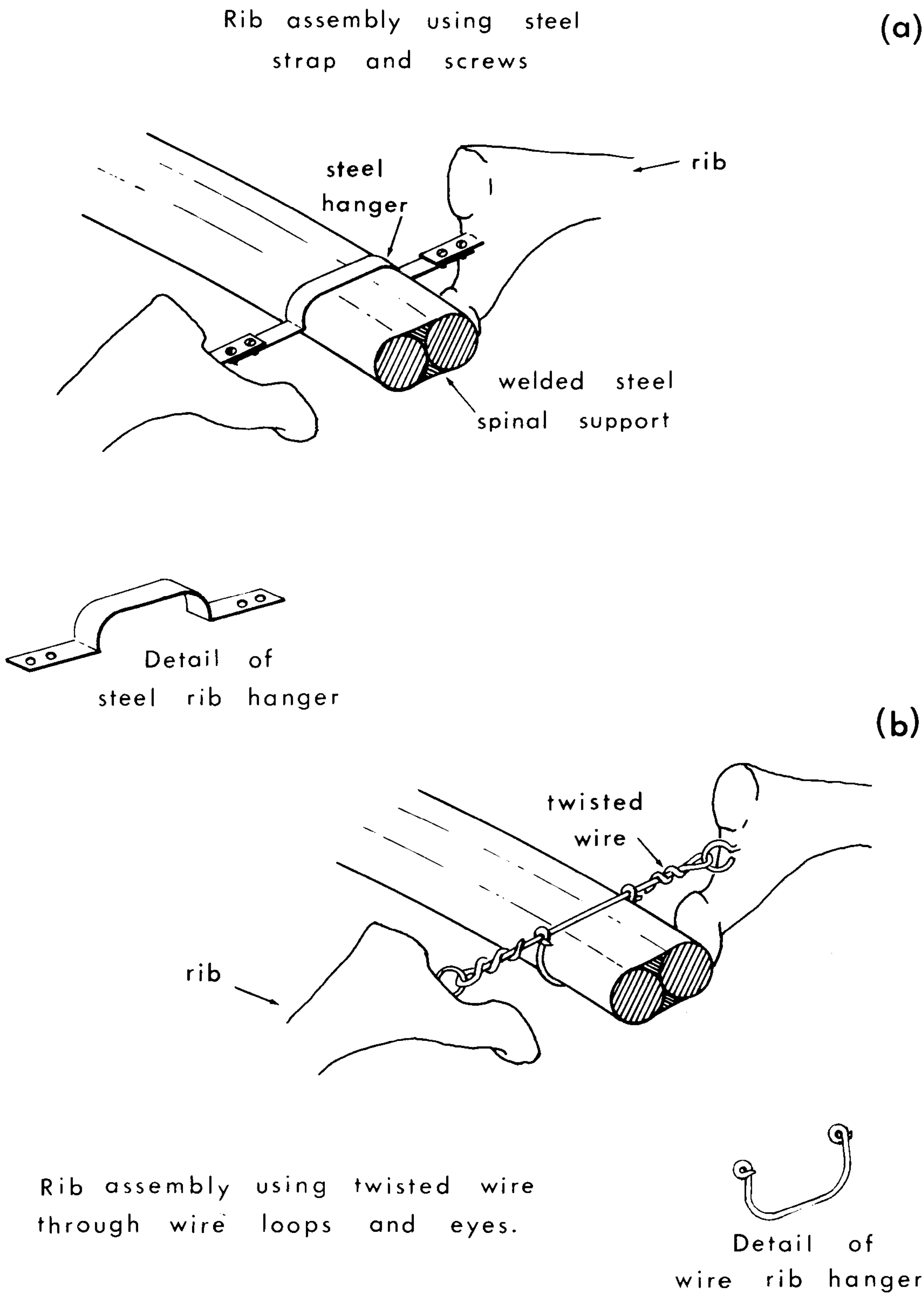
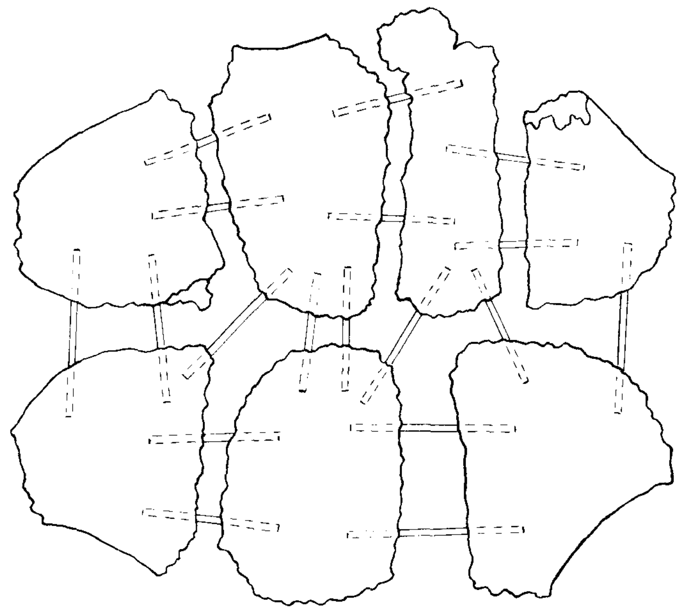


Figure 12. (a) (b) Two possibilities for attaching the ribs to the central spinal support.



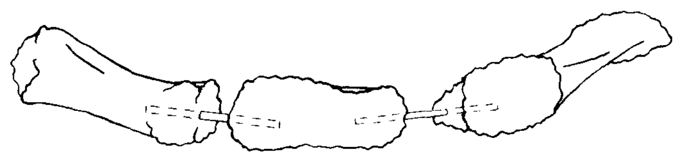


Figure 13. Assembly of sternum.

remaining ribs, except for the last one or two pairs which are floating, will be fastened to increasingly long extensions branching from the attachment for the last pair of sternal ribs to recreate the costal cartilages to the sternum. At first the material for these extensions should be left quite long to be sure there will be enough length to reach all the way to their respective ribs.

The proper curvature and length needed for each wire or rod to be attached to its respective rib-end fitting must then be determined and cut to size. If strap steel is used, small matching pairs of holes can be drilled in the end of each one for attaching it to its proper rib-end fitting with screws.

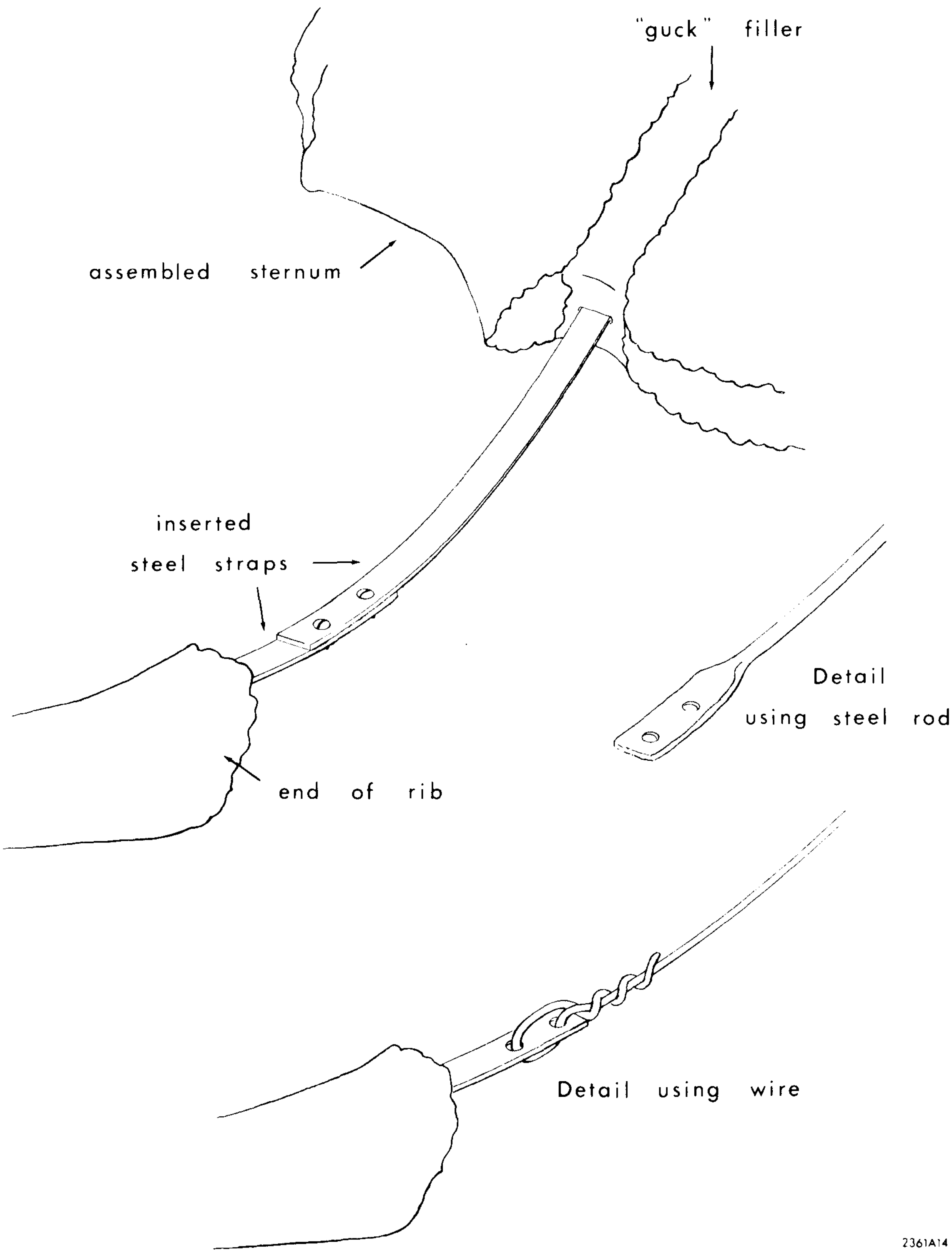


Figure 14. Various ways to attach the rib-ends to the sternum.

If rods are used, the end of each one can be flattened to accommodate the screw holes. If wires are used, the ends of the wires can be woven through the two holes in the rib-end straps and looped back as illustrated in details of Figure 14. Care must be taken that the rods are bent to natural-looking curves and proportions for the appearance of the completed rib-cage.

Then all wires, rods, straps, screws and bolts must be covered over with several coats of "guck", gradually building up the thickness and shape appropriately to simulate the original cartilage, as mentioned previously. This will complete the rib cage assembly. (See photos, Frontispiece, and pages 7 and 8.)

Limbs

Each large limb bone must be drilled through lengthwise so that steel rods can be inserted through them. Once the bone is properly installed on the rod at the desired position and angle, two straight holes should be drilled crosswise all the way through the bone and rod to accommodate 1/4-inch steel pins that will be inserted to prevent the bone from slipping down or rotating on the support. The 1/4-inch rods can be cut a fraction too short so that their ends can be concealed by filling the depression left on the bone with beeswax or "guck" as one does finishing nails in woodwork.

Since the natural position of the limbs will usually require some bend or angle at every joint it will not be possible to slip each bone onto the support rod in succession. At the Smithsonian Institution it has been found desirable to use two lengths of steel rod for each limb, each length bent for one joint, and the two of them joining inside the middle limb bone, the humerus for the forelimb and the femur for the hindlimb. The two rods slide into the drilled hole from the opposite ends and are keyed to fit together inside a steel pipe already installed within the center of the boring of the bone.

The "keyed-joint," as I shall call it, is illustrated in Figure 15. In some cases the assembly of the mount may be greatly facilitated if a keyed-joint is made in each major limb bone. In the event that it becomes necessary to disassemble the skeleton one only needs to push out the locking pins in order to slide the bones off the support rods.

Figure 16 shows the way in which the excessively heavy femur bones of the giant ground sloths mounted at the Smithsonian (see frontispiece) are prevented from rotating on the support rods.

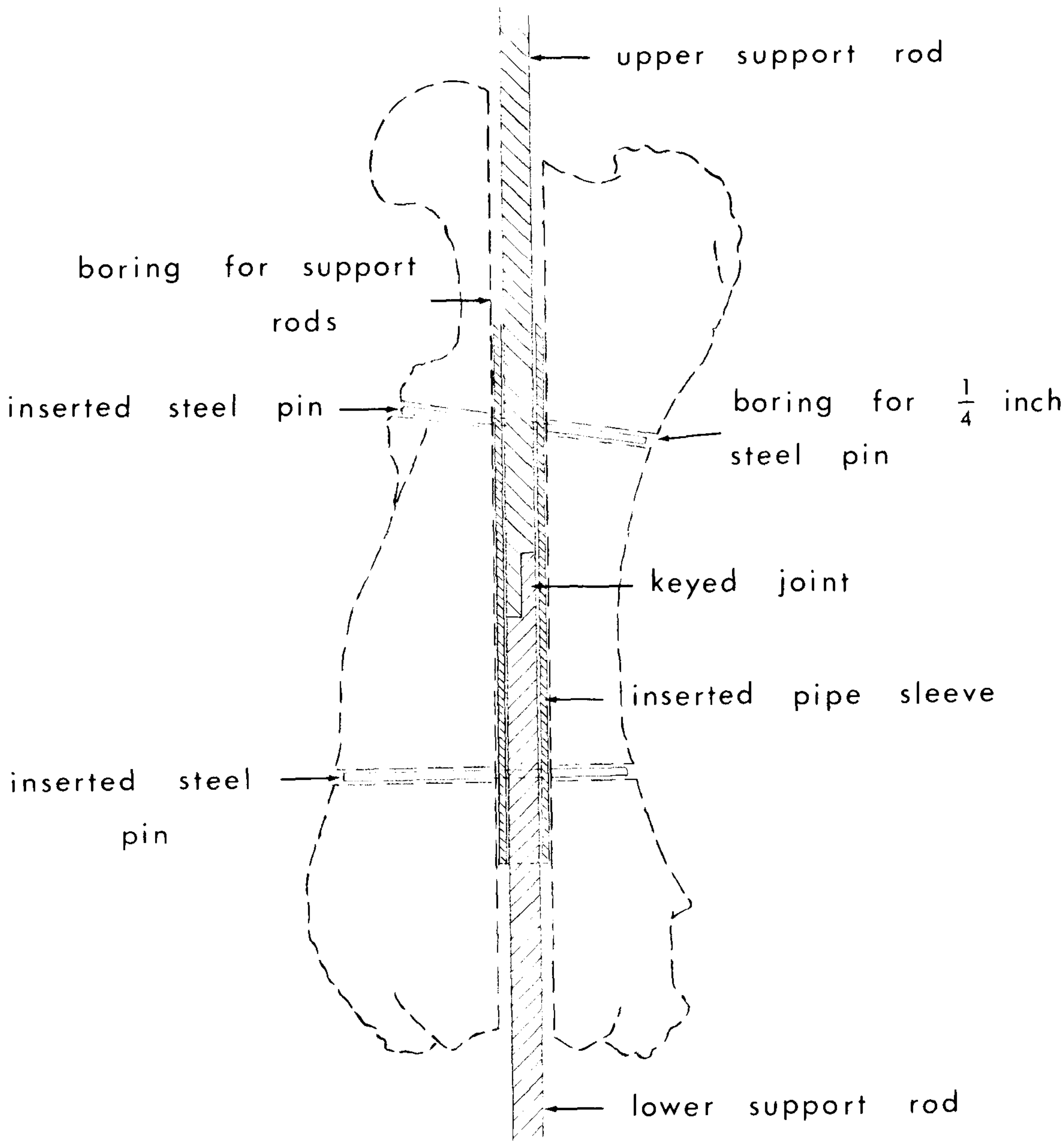


Figure 15. The keyed-joint for limb bones.

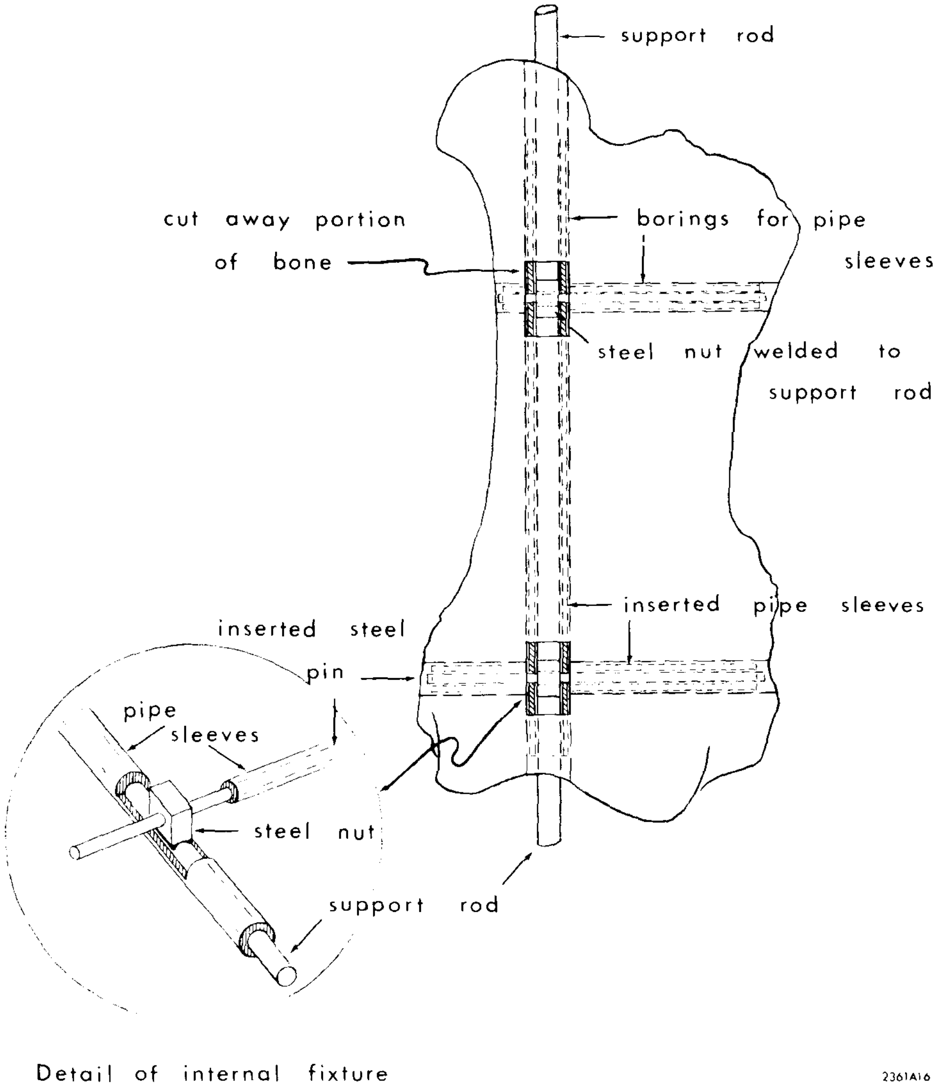


Figure 16. Specialized structure to prevent the rotation of an unbalanced bone on the support rod.

Since the actual fossilized bones are used in this display, each femur is very heavy. As one can see by the diagram, the support rod has to be installed closer to one side to follow a straight line between the joints at each end. To prevent the weight of the unbalanced portion from pulling downward, steel pins were installed at right angles to the support rod through borings lined with pipe for strength and secured to the central supporting rod by the welded-on devices illustrated. These were made of steel nuts welded to the central support through square openings cut from the surface of the bone. Afterwards the removed sections of bone were replaced and the seams patched with beeswax. No keyed joint is possible except near either end of the limb.

The smaller bones of the limbs, such as the fibula of the hindleg and the patella of the knee joint, being of smaller dimensions and secondary to the main structure, can merely be pinned in several places to their respective larger limb bones; see Figure 17.

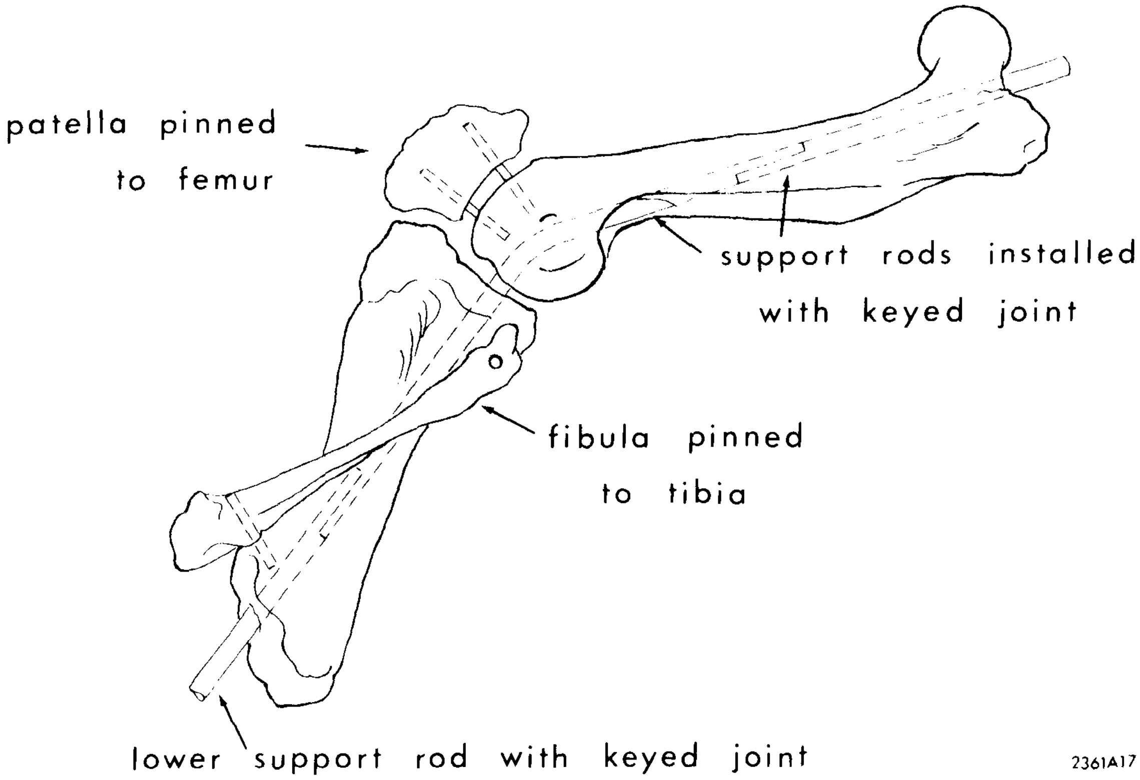
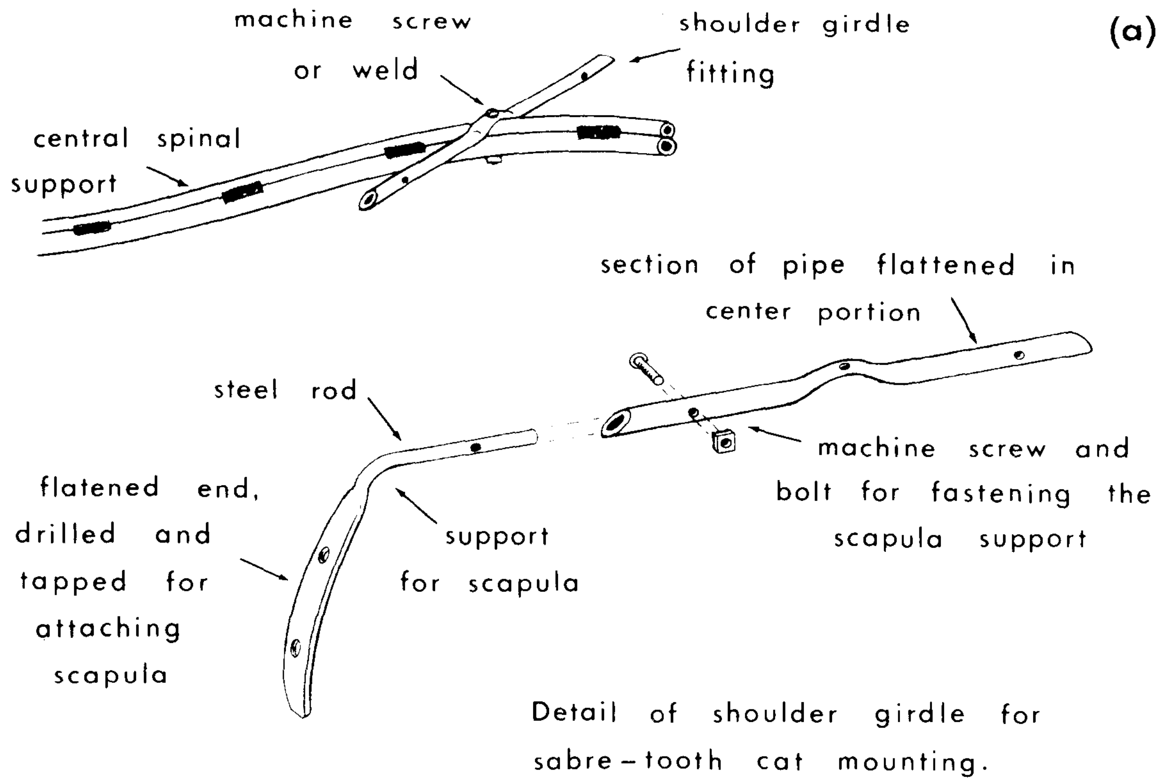


Figure 17. Diagram showing complete assembly of one limb.

<u>Shoulder Girdle</u>

The shoulder girdle must be designed to attach solidly to the central spinal rod and be of strong enough material to support the weight of both fore-limbs including their internal steel supports. A length of black pipe may be suitable for this purpose, flattened in the middle section for fitting over the spinal support and then welded or bolted on to the central support rod between two suitable vertebrae. In this case the armatures for the two fore-limbs can be designed to fit into the two open ends of this pipe and fastened with screws and bolts or bent pins as shown in Figure 18a, taken from the mounting of the Sabre-tooth cat being constructed at the University of Utah by Jim Madsen.



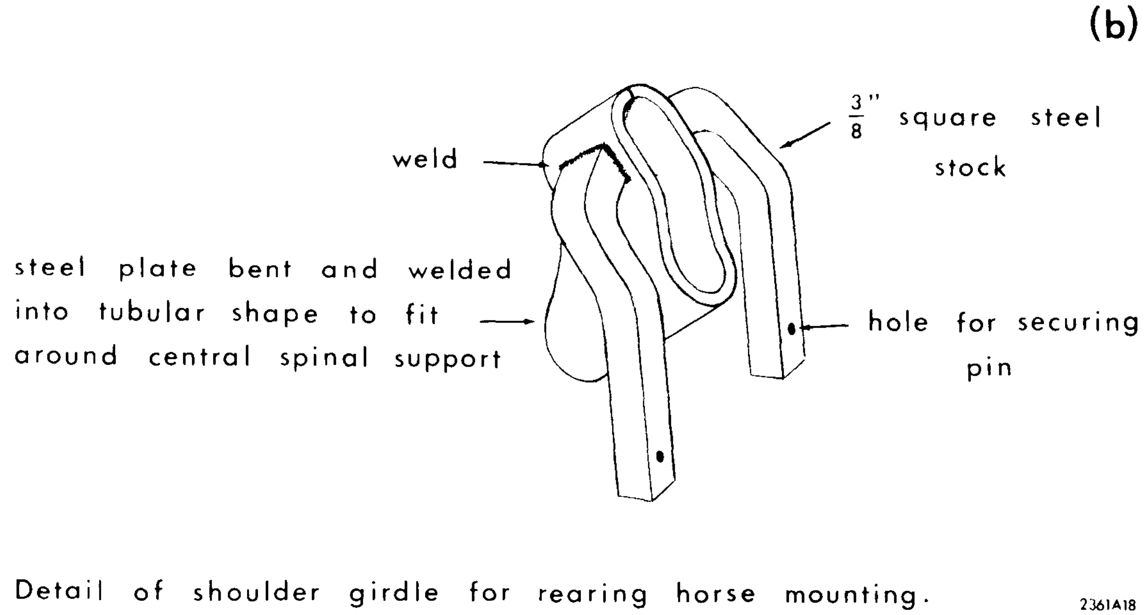


Figure 18. (a) (b) Two shoulder girdle supports.

Another suggestion would be to forge a piece of flat steel stock into a circular or oval fitting made to conform to the outer circumference of the central support rod. Equal lengths of round or square steel stock are then welded on each side for the attachment of the fore-limb armatures. This fixture is placed on the spinal support rod between two vertebrae. It is illustrated in Figure 18b as it is used by Leonard Bessom in the mounting of the rearing horse. Square stock is utilized in making the shoulder girdle, and the upper end of the fitting for the shoulder blade support is provided with a square socket bent from flat steel plate and welded to the end of that support rod. On assembly the square ends of the shoulder girdle are secured into these sockets with small steel pins bent at the top and inserted through holes drilled through both parts. One must be sure to use large enough diameter rod material so the drillings for these securing pins will not weaken the support system.

The shoulder blade (scapula) support is made from round steel rod curved as necessary to contour around the ribs and bring the front legs into a natural position, see Figure 19. At the lower end of the scapula support rod an upright steel fixture of the same size rod material is welded on to accommodate the blade bone. A steel pipe of an equal inside diameter is permanently installed inside the joint of the scapula, which fits over this upright fixture, and during assembly the piece is then secured by a steel pin inserted from the back side of the shoulder blade. This entire apparatus is shown in Figure 19.

Hip Girdle

The hip girdle for the attachment of the rear limbs often presents a more complicated problem, since the pelvic bones are sometimes large, heavy and awkward, and must attach to the sacral bones of the vertebral column, which are fused into a single element of unusual shape. The support system must be sturdy enough to hold the weight of the rear limbs and their internal armatures, and frequently the rear limbs and tail are designed as a tripod mechanism which supports the weight of the entire display, as for example the allosaurus specimens mounted at the University of Utah.

Since I am planning to hang the Paleoparadoxia mounting from two cables attached at two points on the spinal support, the weight of the limbs will not be supported by the floor, so the leg braces and hip girdle will need to be strong

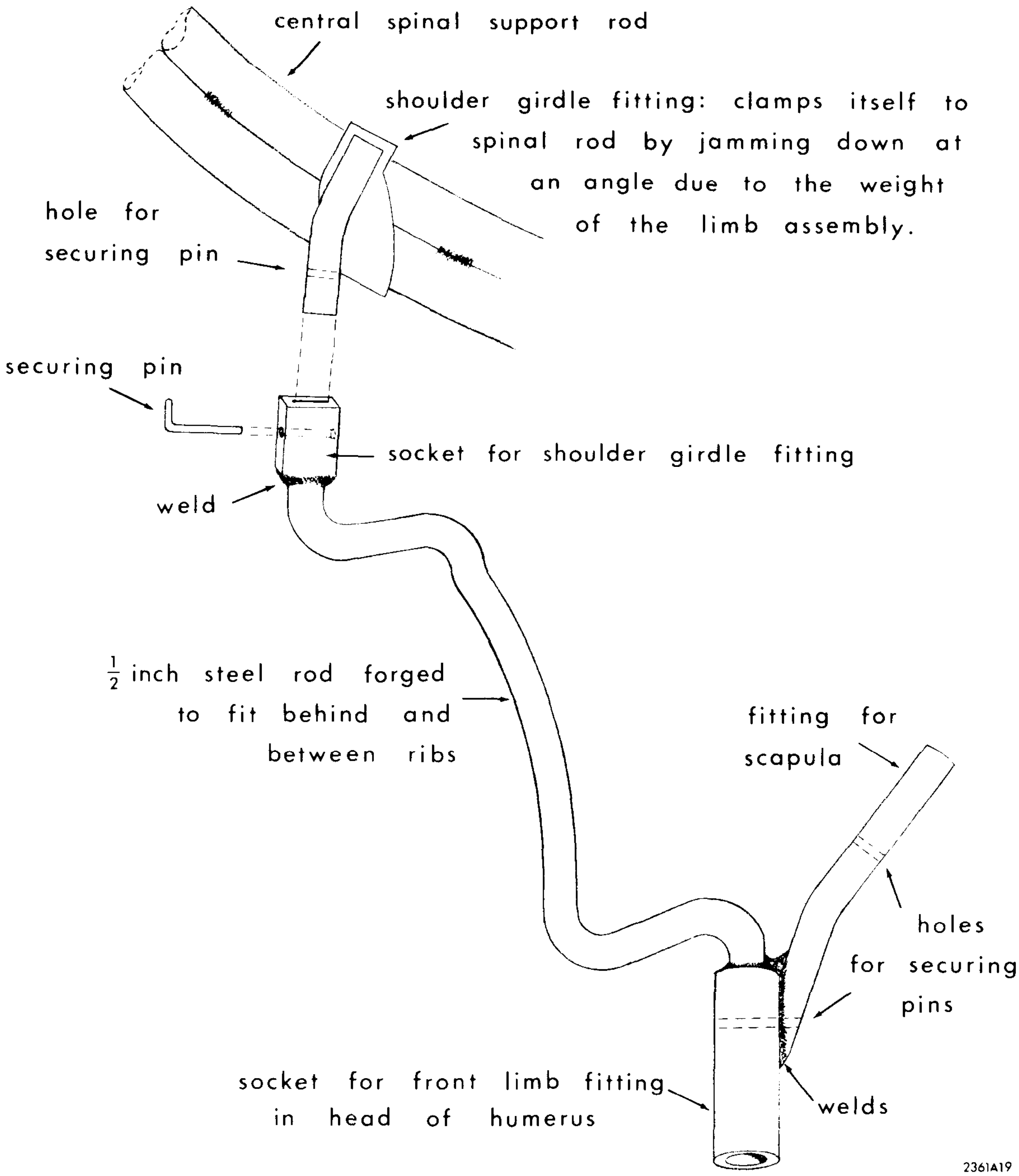


Figure 19. Shoulder girdle and front limb fitting for the Rearing Horse mounting.

enough to carry the weight of the plaster castings and steel supports of the rear limbs, held in somewhat extended positions to dramatize the swimming action.

As the armature for the hip girdle must usually be very sturdy, and must be concealed in the sacrum, this bone often needs to be extensively drilled and cut, and replastered afterward. It is sometimes more convenient to make a mold of the sacrum and cast a plaster piece around the completed fixture, a technique I have seen used both at the Los Angeles County Museum[1] and at the University of Utah in Salt Lake City.[2] Then the cast sacrum becomes a permanent part of the internal support, and must include some arrangement at the rear end for the mounting of the tail, and a welded steel Y or T of suitable strength to provide attachments for the rear limb and pelvic bone supports. It might be better in some cases to complete the pelvic girdle armature with the permanently installed sacrum bone as a separate unit of the support system, to be attached to the central spinal support rod by a suitable fixture. Figure 20 illustrates two different pelvic armatures to give some idea of various ways in which to solve these problems. Figure 20a shows the pelvic girdle of the rearing horse, and Figure 20b shows the same part in the mounting of Jim Madsen's sabre-tooth cat.

Paleoparadoxia's pelvic bones are large and awkwardly shaped, and will need to be attached together at their lower back edges as they would have been in life. Perhaps this can be accomplished with the installation of three or four steel pins, such as will be used to hold together the plates of the sternum, and the space left between the two halves of the pelvis being filled afterwards with "guck" to simulate cartilage and conceal the steel pegs. An extra brace hidden under the forward parts (illia) may also be needed.

Another suggestion which may provide greater strength would be to make a groove in the underside of each pelvic bone along the edges to be attached as I have shown in Figure 21. The grooves could be about 3/4" or 1/2" deep, and at each end of these grooves, a hole would be drilled through horizontally from the inner edge. Then a heavy wire would be strung through the holes and grooves and tightened sufficiently to hold the two pieces in place. The grooves should then be plastered over to the original appearance.

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1. The ankle joints of the rearing La Brea horse mount.
2. The sacrum of Smilodon, the sabre-tooth cat mounting.

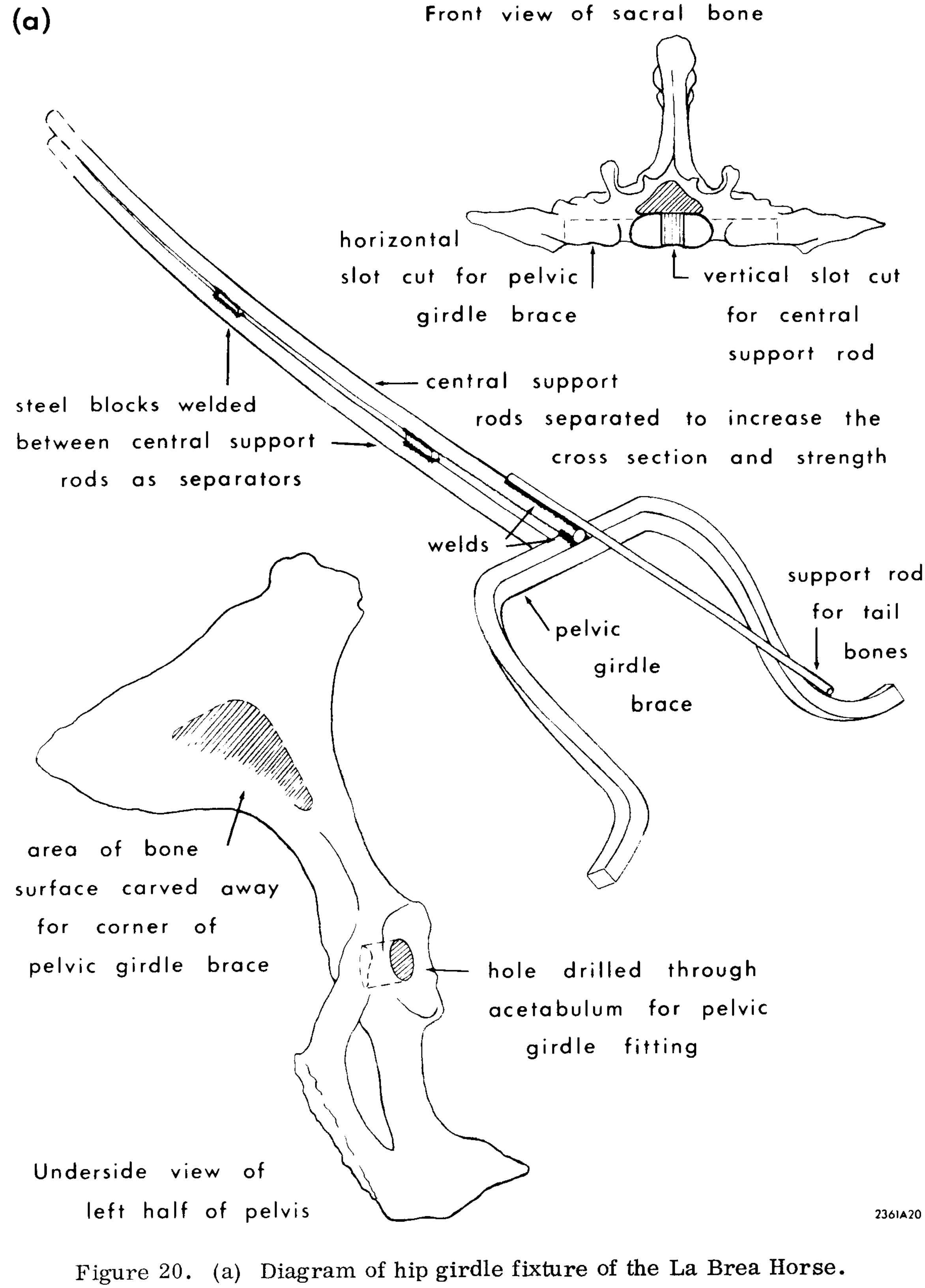
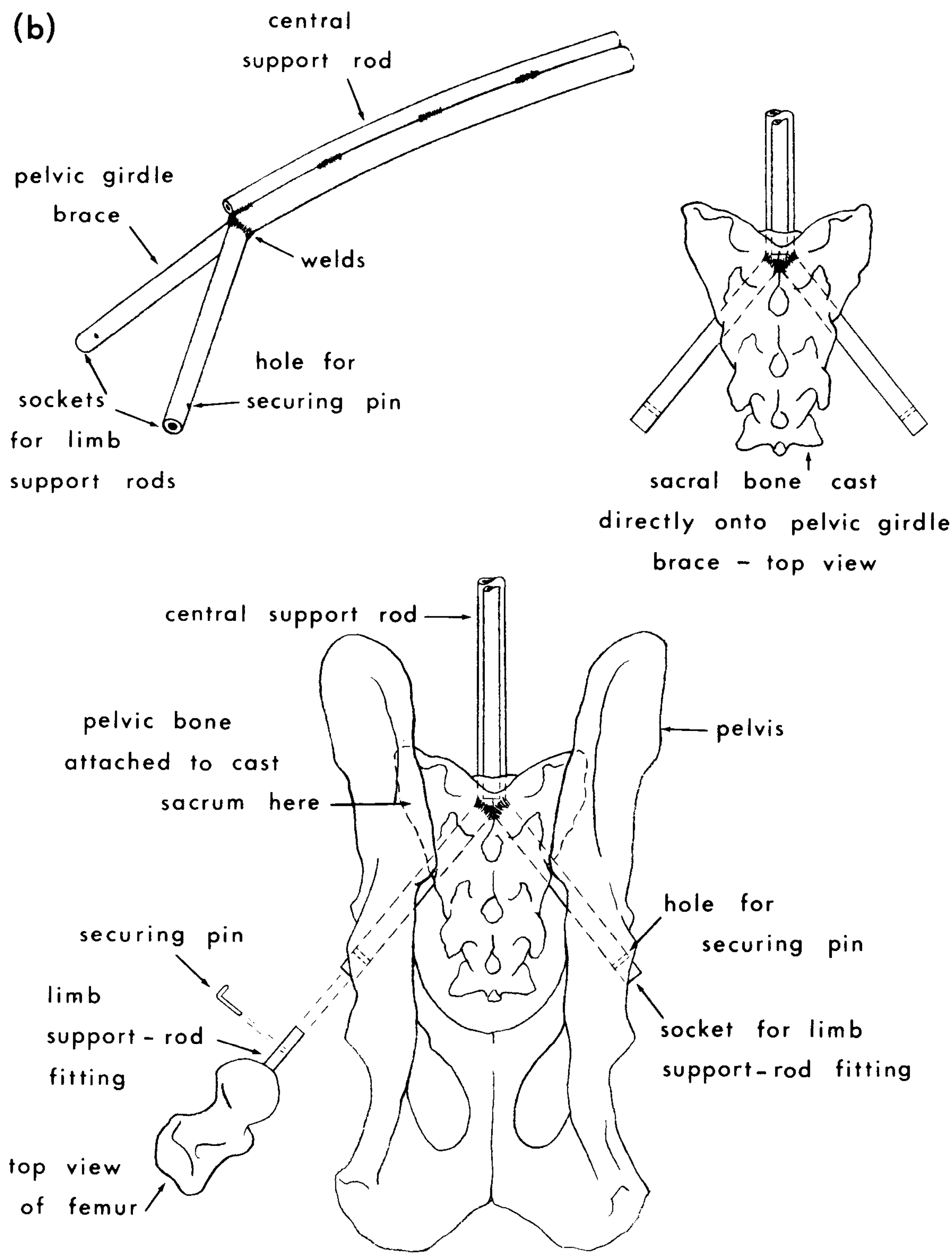


Figure 20. (a) Diagram of hip girdle fixture of the La Brea Horse.



Complete pelvic girdle assembly for sabre-tooth cat mount.

Figure 20. (b) Diagram of hip girdle fixture of the Sabre-tooth Cat.

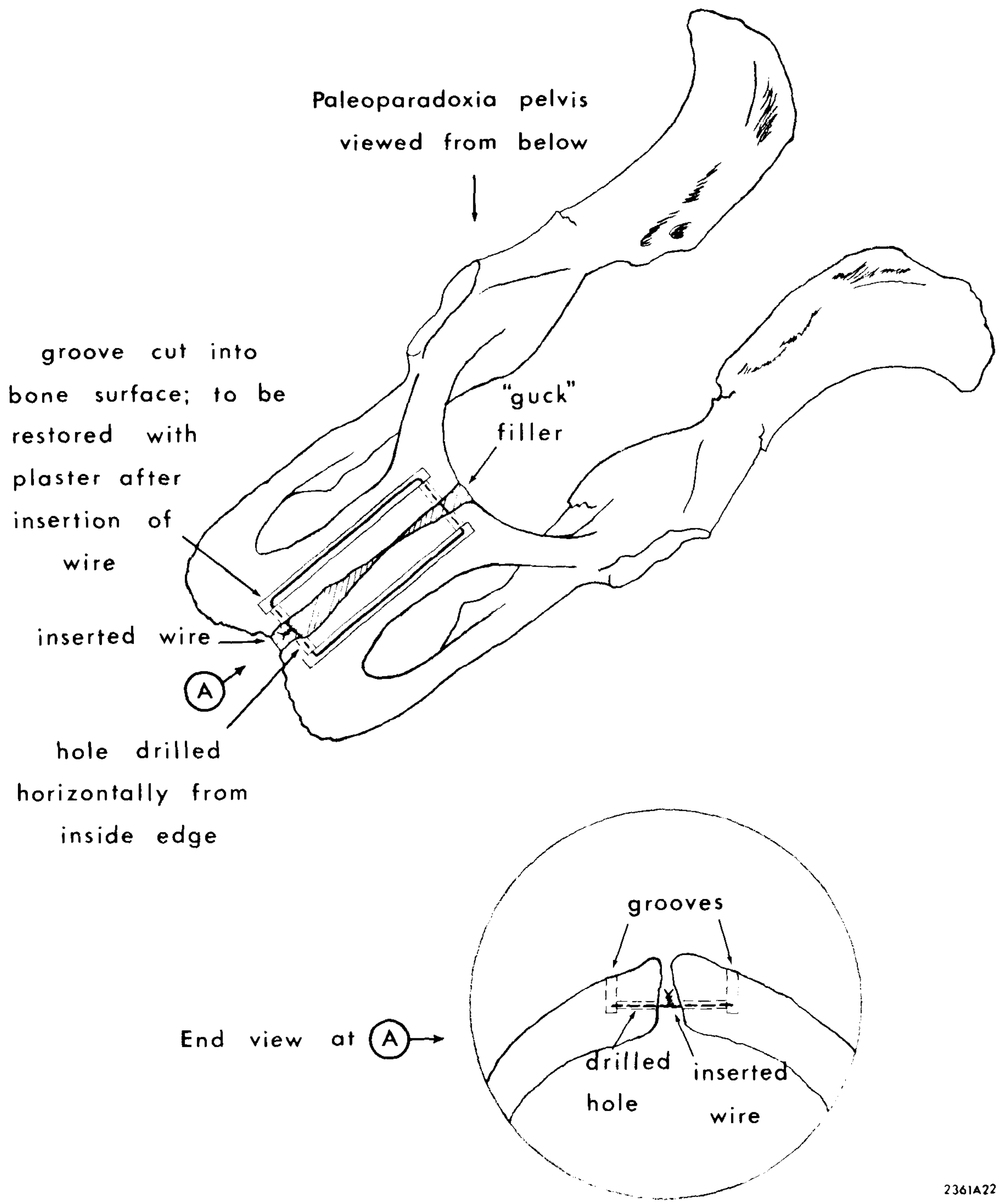


Figure 21. Suggested method for the joining of the 2 pelvic bones of Paleoparadoxia.

Feet

Foot and ankle bones are usually mounted together as a separate unit on smaller diameter steel rods, sometimes using sheet-cork spacers between each bone for natural looking cartilage. The sheet cork can be cut to proper shape with shears or a knife, and artfully rounded with sandpaper on the edges and corners. When mounted between the vertebrae or foot bones, it gives a natural and finished appearance to the model. If preferred, polyethylene sheet foam can be used instead of cork. After the pieces are assembled lightly touch the exposed edges of the foam with a hot soldering iron to give a smooth rounded finish. The sheet cork would be preferable for use between the vertebrae if the model is designed to be assembled and taken apart piece by piece, instead of in prefabricated units.

If the mounted skeleton is to be standing upright on its feet the bottom end of each limb support rod will need to be firmly attached to the floor of the display. This might be done by welding the end of each support rod into a large pipe flange which can then be screwed or bolted down to the wooden base. Or, instead of a pipe flange, a sturdy steel plate of suitable dimensions can be manufactured for each foot to which the end of the limb support rod is welded, and through which holes are drilled for the wood screws or bolts. If the toes are separately mounted it may be possible to also weld to this base plate the separate steel rods supporting each series of toe bones, thereby taking advantage of the extra strength provided through the varying angles of the toes. By way of illustration, Figure 22 shows this type of pedal support as used in the Allosaurus mounting made at the University of Utah. All these support rods are extended several inches beyond the ends of the bones to give working space for the welding and other operations. When the model is completed these extensions will be concealed by the sand or plaster simulating undulating earth which is used to cover the entire base of the display.

The Paleoparadoxia will be mounted in a swimming position, as I have mentioned before, hanging from a structural roof beam by cables, or supported from behind on horizontal steel rods built into a masonry back wall. In this way its feet will not touch the base, but will merely hang above it. The feet will be mounted as separate units and attached at the ends of the limb support rods with concealed fixtures of some suitable design.

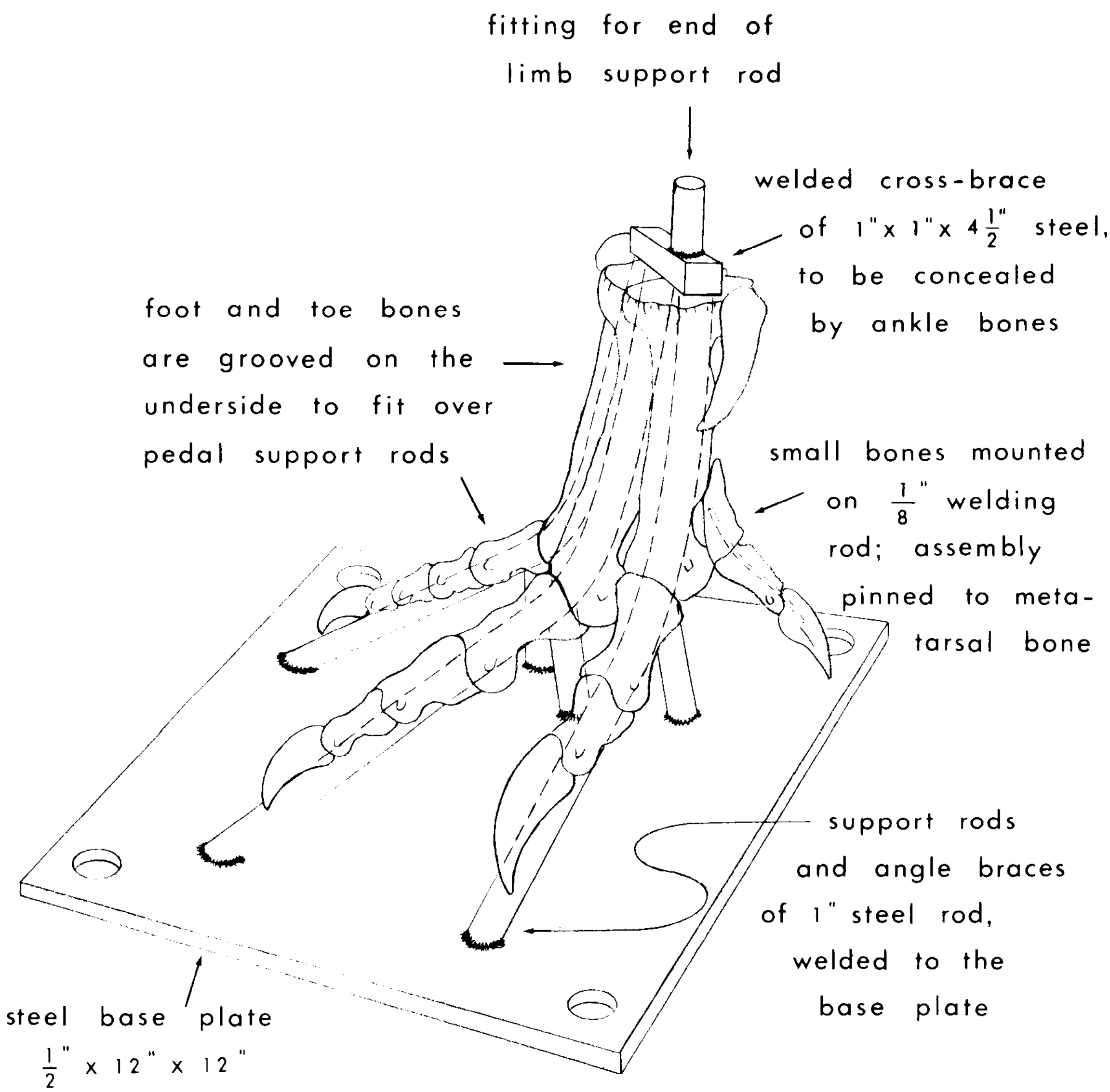


Figure 22. Support System and assembly of the Allosaurus skeleton foot bones.

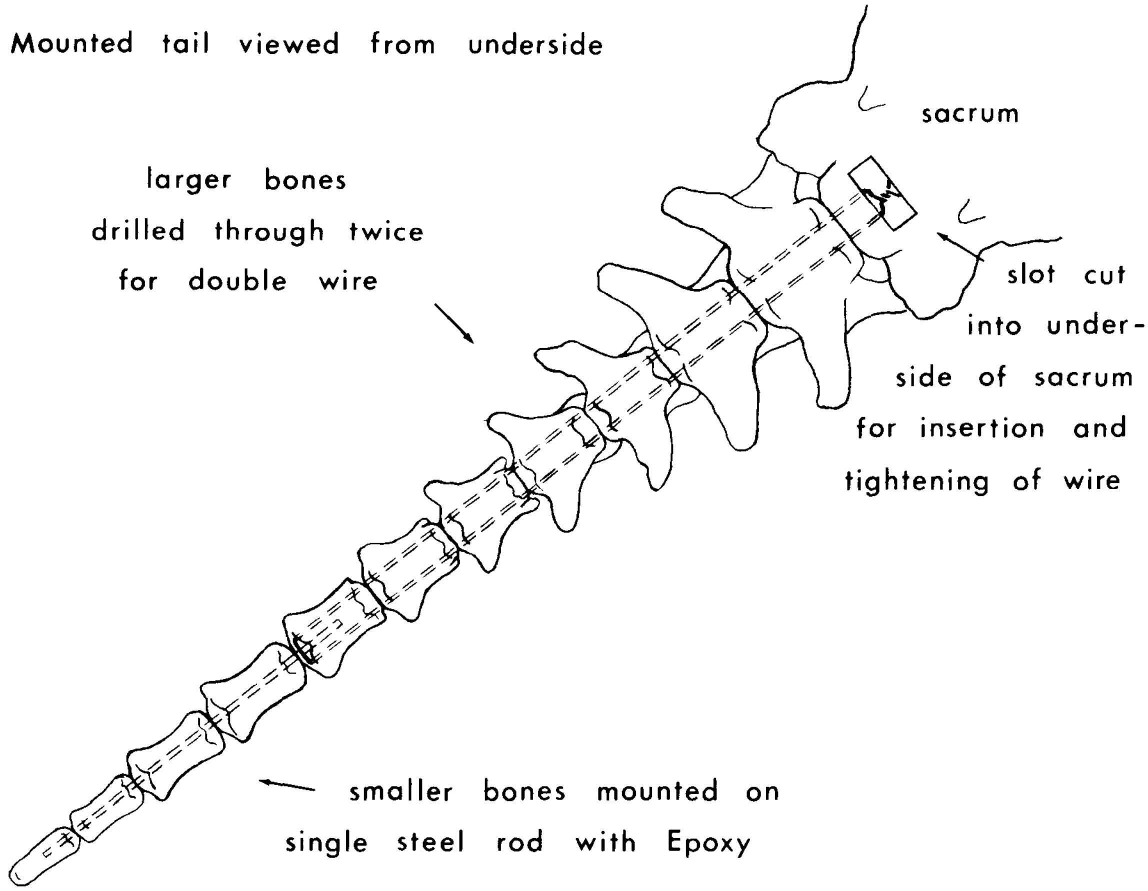


Figure 23. Mounted Tail of the Sabre-tooth Cat, Smilodon.

Tail

The tail bones are usually mounted on a sturdy wire, installed through holes drilled lengthwise through each bone. In some cases the bones are drilled through twice, and the wire is doubled back through each bone, then threaded through holes provided in the rear end of the sacrum, and twisted together for attaching. In Figure 23 I have shown this method as it is used in the sabre-tooth cat mounting.

Skull

Figure 24 (a and b) illustrates the customary method of attaching the mandibles (jaw) to the skull with wire. The length of the wires at the front end will be adjusted according to the desired openness of the mouth. A length of steel pipe will need to be installed into the brain case of the skull, of the correct I. D. to fit over a steel rod extension of the central spinal support.

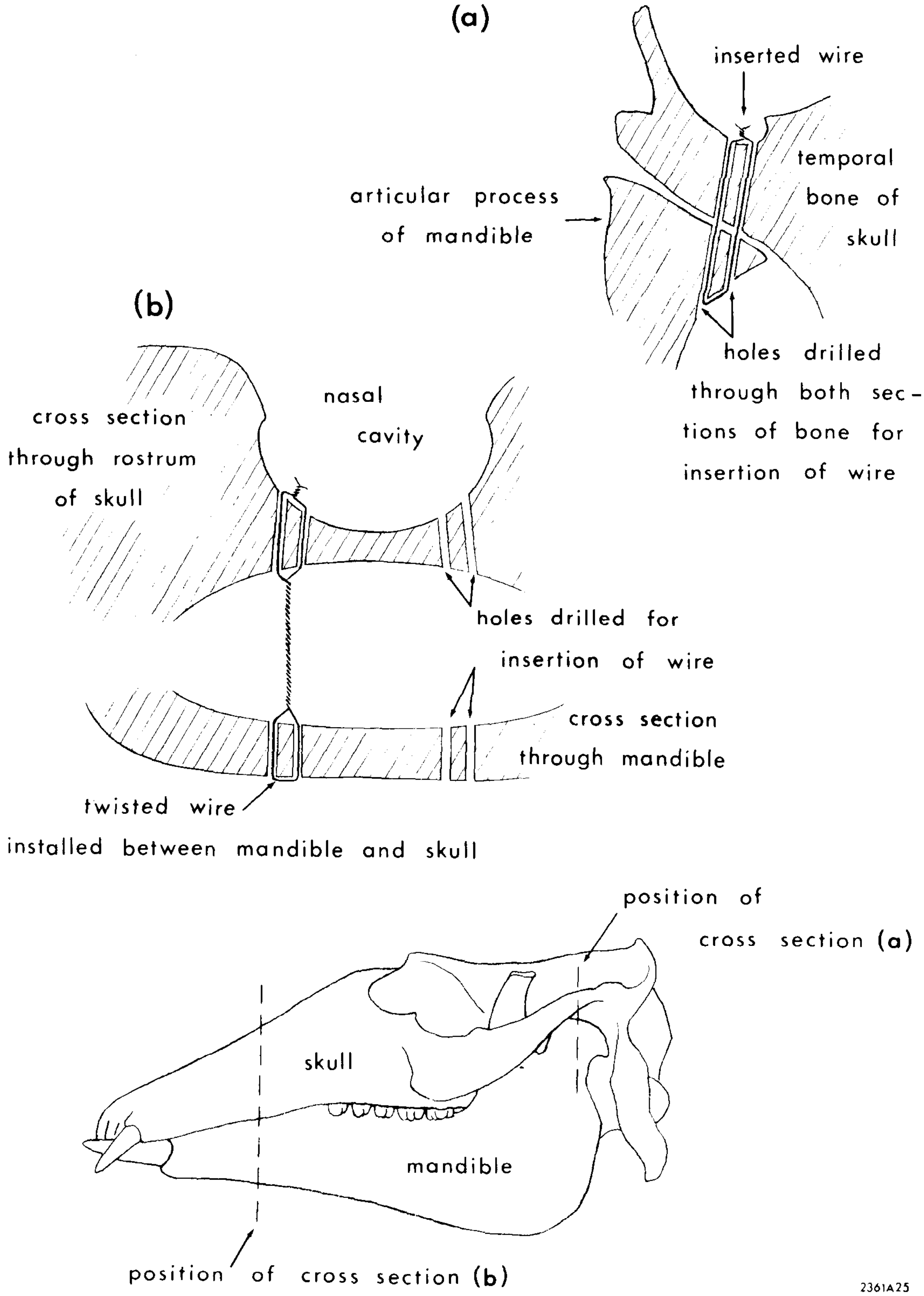


Figure 24. (a) (b) Detail diagrams for the attachment of the jaws to the skull.

This rod will be arranged to extend beyond the cervical vertebrae (neck bones) by the required amount. If the skull is to be mounted in a downward position, bolts or securing pins will be needed to attach it to the rod. It is also possible to reverse this arrangement by installing a length of rod in the skull, which can be bent appropriately, and which protrudes from the base of the skull to be fitted into a socket provided within the cervicals at the front end of the spinal support.

Assembly

The order of assembly must be planned along with the engineering of the support system. In general, I would think it best to begin with the spinal support rod, on which one first assembles the sacrum and pelvic attachments at the rear end. Then lumbar vertebrae with spacers are threaded on in order from the forward end, last one first. The thoracic vertebrae will have to be threaded on alternately with whatever provisions are being made to attach the rib cage. At the proper point in this section the shoulder girdle must be installed. Then the cervical vertebrae are threaded on, and the skull placed last. The rib cage can then be attached. If the display is to be a standing skeleton, the feet and limbs will need to be mounted on the base before their attachment to the shoulder and pelvic girdle fixtures. Tail and toe bones, and other details may be planned to be added after the main structural parts are assembled.

In the case of very large displays, such as dinosaurs, it might be better to make up the mount in separately completed units, such as limbs, pelvis, thorax and several tail sections, which can be fitted together with concealed appliances in the final assembly.

In my visits to these museums and laboratories I have found that each display and each skeleton presents somewhat different problems, and their solutions give lots of opportunity for innovation and ingenuity in the engineering of the support systems, choice of materials, and application of techniques. A great deal of artistry must be combined with the mechanical part of the work, and each craftsman develops his own favorite methods. Also, I found that new materials are constantly becoming available, such as fiberglass pipe, rod, or other form, plastics and special casting plasters, and many times their use might be advantageous over the more conventional products.

Recipe for "Guck"

Ingredients:

Crystals of Butvar (a polyvinyl acetate resin)
Acetone
No. 70 ground asbestos powder
Dry dental plaster powder

First prepare a thick solution of Butvar in a gallon can or container that may be kept tightly closed. Half fill the can with Butvar crystals; then add acetone to nearly fill the can and stir. Butvar is slow to dissolve, so the preparation of this solution should be started a day or two in advance and stirred occasionally.

When ready to make up a batch of "guck", mix together equal quantities, by volume, of dry plaster and No. 70 ground asbestos, and stir the mixture into enough of the Butvar solution to make a paste of putty consistency. If more guck is being made up than will be used immediately, a wide-mouth container that can be closed tightly should be used for the mixing. Dry pigments may also be added at this time if desired. Uncolored guck is a light gray color when dry.

Apply the guck with a brush, putty knife, spatula, or fingers. It can be applied in thin layers and gradually built up to any desired thickness. It sets hard as the acetone evaporates out. When hard, it can be worked with a knife, rasp or sandpaper for finishing, and can then be painted with any paint that one may be using on the mount.

SPECIAL TECHNIQUES FOR PLASTER RECONSTRUCTIONS

Most mounted skeletons have at least some cast plaster elements, which are mainly the reconstructions of those bones missing in the original find. Often, as in the case of the Stanford Paleoparadoxia that I am mounting, the entire skeleton will be of plaster, in part cast from molds made on the original bones, and in part reconstructions. The reconstructions of the missing bones of our Paleoparadoxia specimen are being originally modeled in oil base clay, and then latex rubber molds and castings of the same dental plaster as was used on the original cast pieces are produced from these clay models. All the molding and casting work is being done in the preparation labs of the Paleontology Department at the University of California in Berkeley by Mr. Lester Kent and other members of the staff. The completed clay reconstructions must be coated with Glyptol, a varnish that can be used on oily surfaces, before the application of the latex, as the oil in the clay has a deteriorating effect on the rubber of the molds.

The dental plaster being used in this display is Glastone, a fine quality material which produces very nice castings with excellent detail. As discussed before, it is possible to do as much trimming, cutting, and patching as may be necessary on the plaster replicas, and details of surface cracks or chips can be carved in with a pocket knife or other suitable tool. Striations, such as the grain texture of bone surface, can be produced with careful manipulation of coarse sandpaper. Carving and shaping can be somewhat facilitated if the surface of the piece is dampened with water to soften it. If any portion of a casting needs to be enlarged additional plaster can be added to the original surface, and then carved and shaped to size. To assure that the fresh plaster will stick, the piece should first be soaked in water and the wet plaster daubed on to the damp surface. If this is not done the dry piece will immediately absorb all the water from the mixed plaster so that it crumbles before it sets.

I shall describe the technique taught to be by Lester Kent for repairing broken plaster pieces, which is often difficult to do. However I have had extremely good success with this method, and have used it also to attach on the reconstructed portions of our original imcomplete pieces. I am extremely grateful to Les Kent for having taught me this technique, for I have needed and used it many times already.

1. First soak both plaster parts completely in water for at least one-half hour, or until no more air bubbles appear.

2. Mix a small amount of plaster with water to a thin consistency, like heavy cream.

3. Working fast, coat both surfaces to be attached with the mixed plaster.

4. Place the pieces together in the sand table in a previously prepared depression of exact shape that is lined with Saran Wrap to keep sand out of the mend. The sand will need to be quite damp to hold its shape sufficiently.

5. Press the sand firmly around the sides and ends of the mended piece to help clamp the two portions together. Avoid motion between the two parts after the plaster begins to set.

6. If it can be done without disturbing the mend, one can try to wipe off some of the excess plaster around the patch before it sets hard. If this would jeopardize the mend, the extra plaster can be chipped off after the piece is dry and the original surface restored as described earlier.

To cast a small bone or part in a hurry, where surface detail will not be too important, one can make what is called a "squeeze mold." This is made with soft oil clay squeezed around the original piece. Use talcum powder for a parting compound. This should be applied to the original piece, and to the area of the seam between the two halves of the mold. Press two portions of clay around the original to be copied, in sufficient thickness to make a sturdy mold, perhaps one-half inch or more thick. Press the clay carefully around the piece and arrange the seam between the two parts for a tight fit to minimize the bead that will form on the casting. Around the outside perimeter of the separation make matching index marks on both sections, so the two parts of the mold can be put together again accurately. Make a funnel-shaped pour hole at a convenient spot in the separation seam. Now open the mold without distorting its shape and remove the original bone. This type of mold can be used to cast a plaster replica of a bone permanently around a prefabricated fitting in place of drilling out the original. When the fitting has been manufactured, arrange the squeeze mold around it in the desired position, and pour the plaster right on to the metal.

All the plaster portions of a mounting will need to be painted to simulate real fossil bone. This should probably be done after the support system has been completed but before the bones are assembled on it. Before starting to paint, each piece needs to be checked over for undesirable remains of plaster from the casting process, seams and burrs, etc. All the decorative carving and marking must also be completed. Then the pieces should be cleaned to remove water soluble ink markings, greasy fingerprints, smears of oil clay, etc. Perhaps soap and water or dry-cleaning fluid would be suitable for this. Rinse and dry well.

Any paints can be used, such as artist's oils, oil base wall paints or latex wall paints, but the paint should not give a high gloss finish. Often it is desirable to first paint the pieces with a sealer such as shellac, applying several thin coats. Then a base color can be painted on using dry pigments mixed into the shellac, matching the original color as closely as possible. As fossil bones are usually colored and marked by several mineralization processes their outer surfaces are variously stained and colored, and to simulate this most preparators develop antiquing processes for the final coat of the painting. One method, described to me by Frank Pearce, is to use various shades of dry pigments with shellac, painting the surface details by hand with artists brushes, mixing the various colors for the best tints directly on the brush. Dip the brush first in the shellac, then in the pigment powder. An adequate selection of dry pigments should be obtainable in a good paint store.

The dinosaur specimens from the Cleavland-Lloyd Quarry in Utah are a deep grey-black color, and the method developed to simulate this surface uses a black acrylic spray paint, antiqued with white shoe polish diluted with water.

Another interesting process that I learned from Leonard Bessom, for matching the color of plaster parts to the fossil bones found in the La Brea Tar Pits is accomplished by boiling the plaster pieces in tar for a while. This gives excellent results, the plaster pieces exactly matching the real bone.