Reproducing Our Ancestors
The University Museum’s Casting Program

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A hundred and thirty-one years ago, quarry owners in the Neander Valley ("Tal" in German) came across the mineralized remains of a brutish-looking, primitive creature (Fig. 1). For several years, there was considerable debate as to the nature of this animal. Initially identified as a bear by the quarry owner, the fossils were later considered to be the remains of a modern human. Strange characteristics of the remains, such as the long, low form of the skull, the heavy brow, and the shortened body, were explained as the result of disease or foreign origins, so that the Neandertal bones became a person who had been washed away by Noah’s Flood; an ancient Celt or German; or a Mongolian Cossack who wandered from the Russian cavalry. But by 1864, following the publication of Darwin’s *The Origin of Species*, the Neandertal bones took their place as the first human fossils to be recognized—the initial testament to the evolutionary development of our species.

Since that time, many additional bones and teeth (not to mention tools of stone and bone and even artistic works of great power) have furnished more documentation of our biological past. The most primitive of the fossil remains are 5 million years old, and illustrate our evolution from small-brained, ape-like creatures.

Though many of these fossils are broken and incomplete, and have been distorted through their long interment in the ground, they represent our only direct links with our ancestors of 100,000, 100,00, 10,000, and even 1 million generations ago. Studying them reveals the pathways followed by our line during its long evolutionary journey, and provides precious insights into the nature and origins of modern human biology and behavior.

Recently, the Casting Program of the University Museum has looked into ways to preserve these fossil specimens. In most cases, the original bones remain in the countries where they were found. Using modern plastics and synthetic rubber technology, we have been developing techniques and procedures that can be used to produce replicas that are as accurate as is possible. The need for such a project becomes clear when we consider how scientists study fossil bones and the fate of many already discovered specimens.

The Value of Fossil Casts

In the 1900s, and the (by today’s standards) primitive molding media. Although no cast is an ideal substitute for the original fossil, in this case, the casts represent the only record of these specimens, and provide a reasonable alternative for the missing originals.

The loss to science of the Peking Man fossils does not represent the only such disaster to befal the bony relics of our evolution. During the final stages of World War II, the museum in Brno, Czechoslovakia, was heavily damaged. In the resulting fire, much of a collection of 20 skeletons recovered from the unique Upper Paleolithic sites of Predmosti was destroyed. Unfortunately, only two Predmosti specimens, both skulls, were molded and cast prior to their destruction. These casts have become the “types” considered representative of the original sample of bones. An examination of photographs of other specimens pictured in a 1934 monograph, however, shows that the collection was a variable one. We may speculate as to how different our views of the origin of modern humanity might be today if the Predmosti samples (or sample casts) had been preserved into the period after World War II, when our appreciation of the evolutionary significance of population variation began to develop.

Often, ancient bones are held together by toothpicks and bits of wire.

1. An artist’s reconstruction of a neandertal (left) makes this extinct ancestor of ours seem to rise out of the depths of time. On the right is the fragmentary skull of the neandertal fossil from the Neander Valley. The large projecting area at the brow is characteristic of this group of humans and, along with the large face, dominates the reconstruction.

2. Cast of a lower jaw bone from the site of Zhoukoudian. All that remains of the fossils found at this site are a series of superimposed casts. Technicians were able to produce casts of high quality using materials that, by today’s standards, were very primitive. Note that on the surfaces of the teeth the details of cusps, ridges, and cracks are finely replicated.

3. BELOW: mold with two of the plaster of Paris sections removed to show the internal cavity. For cast production, each of the sections of the mold would be waxed and set plaster poured into the cavity. When the plaster dried, each of the mold sections would be removed from the cast.
Comparison of a Barlow cast (right) with a Wenner-Gren Foundation cast (left). Both of these casts were made from molds of the Kabuso fossil skull but reflect changes in molding and casting technology over the last 50 years. The Wenner-Gren Foundation cast, made in the 1970s from a silicone mold, preserves more detail of the fossil bone and is dimensionally accurate. The Barlow cast, made in the early part of this century from a plaster-of-Paris mold, preserves less fine bone detail.

Inclusion of fossils in a museum collection does not guarantee their safety. Ancient bones are very frequently fragile; some are only partially mineralized or fossilized, others are not mineralized at all. Often, they are held together by toothpicks and bits of wire. With the interest in human origins expanding year by year, and the number of professional scholars involved in active research steadily increasing, these fossils are being handled, examined, photographed, measured, and broken with greater frequency. Many researchers have had the experience of examining a fossil they had first looked at several years before, only to find that, due to handling or an accident, the fossil specimen is now different in appearance. This is a sensitive area in paleoanthropology, but one case that can be discussed is that of the famous South African specimen Sterkfontein Skull 5 (Sts 5), the most complete example known of the skull of Australopithecus africanus. In 1950, Sts 5 or "Mrs. Ples" was accidentally dropped. There was considerable damage to the top of the skull, with serious loss of bone. The reconstructed skull differs from the original in form, but the exact nature of the difference has been the subject of much debate. Less dramatic is the damage caused by simple wear and tear. Many famous and important fossils have been measured so often that there are actually grooves or pits in the places where measurement landmarks are located. Hominid fossils dating to the Later Pleistocene, sometimes not completely mineralized, are literally worn away as they are handled. In the labs and offices where such fossils are studied, numerous tiny flakes of bone are often found lying around the work tables and storage drawers. Though this is not the situation in Kenya, concern for the fossils has led Richard Leakey to propose a five-year moratorium on the examination of fossils housed at the Kenya National Museum in Nairobi. There is serious concern among some scholars as to what will remain of all hominid fossils a hundred years from now.

Molding and Casting of Fossil Bones: A Brief History

During the 19th century, a large array of molding and casting media was employed in making replicas of fossil bones, but plaster was by far the most widely used. For example, in 1900 the Carnegie Museum spent a considerable sum to mold a complete dinosaur skeleton, whose plaster-of-Paris casts were later distributed to many other museums around the world.

In the 1920s and 1930s, F.O. Barlow, a leading mold and cast maker in Europe, fabricated more than 600 plaster-of-Parises of hominid fossils. In order to ease the removal of plaster from an often fragile fossil specimen, these molds were made of many pieces, waxed and tacked to each other. A complete mold of a skull, for example, could easily be composed of more than 100 plaster pieces, each replicating a small part of the whole fossil; fitted precisely together, they form what can only be described as a large three-dimensional jigaw puzzle. Casts produced by Barlow’s molds have a surprising amount of detail. They appear to be dimensionally accurate replicas, but many cannot be adequately assessed because the original fossil has been modified, reconstructed, or even damaged. About 500 molds of fossil hominid fossils have survived, and are now in The University Museum Casting Program (Fig. 1).

One of the outstanding features of the Barlow collection is the precise reflection of many of the anatomical features that remain in the early part of this century. While it is sometimes difficult to discern in the fossil’s history, the Barlow mold represents, those made relatively soon after the fossils were found should preserve the bone in a condition close to that at the time of excavation.

Other molds, made after fossils, had been reconstructed, are of historical interest, providing an important glimpse into the ways by which a fossil specimen may change as a result of modern human interpretation. Many of these specimens have been "re-constructed" since Barlow’s time, and to other expectations and different interpretations of the human fossil record.

Since 1932, when the Barlow collection was housed at The University Museum, the molds have been used to produce casts. For practical reasons, latex rubber molds were made from the plaster-of-Paris originals. From these, thousands of fossil casts (including the original Neandertal finds, those from Cro-Magnon, Pe- king Man, and the Taung child) were made and distributed to hundreds of museums, colleges, and universities. Because for many years it was the major source for casts, it is not an overstatement to say that The University Museum provided several generations of scholars with their only replicas of hominid fossils.

In the 1920s, the Wenner-Gren Foundation for Anthropological Research sponsored research which led to the development of new molding and casting techniques and the introduction of more modern materials. Lili Osmundsen, Director of Research for Wenner-Gren, did the need for more accurate and detailed casts of fossil hominid bones. The Foundation enlisted the services of plastics expert David Gilbert, who spent a number of years developing new procedures for employing newly introduced synthetic silicone molding rubbers, and a variety of plastic casting resins.

From 1952 to 1976 the Wenner-Gren Foundation sent mold makers all over the world. Using techniques developed by Gilbert, they were able to produce over 3000 molds of the most famous human and primate fossils, including Zinjanthropus or "Nut Cracker Man," Mrs. Ples and the Taung child from South Africa, and Kabwe Man. During this time the Wenner-Gren Foundation produced nearly 10,000 high-quality plastic casts of fossil remains, and distributed them to scientists and researchers and teaching institutions throughout the world (Fig. 4).

A major objective of the Wenner-Gren program was the development of methods to ensure that the accuracy and details captured by the silicone rubber molds were maintained over time. This crucial need was met by the concept of the "pattern," a device that stores the form of a fossil, and permits many generations of highly accurate casts to be produced (see below). Such patterns form the core of a new project intended to safeguard for posterity the fossil bones documenting human and primate evolution, in replica form.

The 300 Wenner-Gren molds and patterns and the 500 Barlow plaster-of-Paris molds form the nucleus of this repository of bone replicas, established by The University Museum with the support of the National Science Foundation and the Wenner-Gren Foundation. It is the first and only repository of this type in the world. Using the techniques developed by the Wenner-Gren Foundation, another 300 silicone molds have been added to the collection by University Museum mold makers, and the Casting Program is dedicated to adding new molds in the future. The National Science Foundation is funding the production of patterns, and the long-term curation of both molds and patterns.

The Casting Process and the Importance of Patterns

A mold is a negative impression of an object (in this case a bone) that is used to make a positive impression. Both patterns (stable epoxy positives or duplicates of a mold) and casts (positives of the bone itself) can be made from molds. While molding and casting are relatively familiar concepts, pattern making is not. Its importance within the casting pro-
cess derives from the specific technology used to make highly accurate reproductions. A general description of the way in which a fossil cast is made is presented below; technical details are given in the accompanying box.

The Mold

A mold is an impression made on the original fossilized bone or tooth (Fig. 5). Since museums safeguard the fossils in their care, making a mold usually requires that the mold maker travel with his or her equipment and supplies to the country where these bones are housed and curated. The mold itself is made from a flexible material, today usually silicone rubber; it is backed or strengthened with a solid material, usually a very fine-grained gypsum cement.

Why isn’t a mold, a highly accurate negative impression, stored as the permanent representation of a fossil bone? In order to be safely removed from a delicate bone or tooth, molds must be made of a flexible substance; this is usually a synthetic silicone rubber, but latex rubbers also have been used for this purpose. Over time, these flexible molds lose the property termed “memory,” which allows the mold to return to its original form after it has been distorted—as in pushing or pulling out a rigid cast. Also, the tear strength of the mold is lost over time: when a mold is stretched it should return to its original form; if instead the mold tears when stretching pressure was applied, the mold becomes unusable. When memory and tear strength are lost, the flexible mold ceases to be an accurate record of the original fossil. There is thus the necessity for a stable copy of the mold, a pattern.

The Pattern

Figure 6a-f illustrates the stages involved in pattern production. Each stage serves to guarantee that the pattern will be a most accurate and stable representation of the fossil bone. The specific fossil illustrated here (Fig. 6f) is the upper jaw of a 13-million-year-old ape-like creature. This bone was molded in 1982 in Budapest, Hungary, by University Museum mold makers. With the permission of the excavator, the mold was brought back to the United States and became part of The University Museum’s collection. Pattern production took place in 1983.

A pattern is like a cast in that it is a positive impression taken from a mold. A pattern, however, is a positive not just of the hollow in the mold that replicates the fossil, but also of the complete mold section. So a pattern is a positive of a bone or tooth as it was being molded, and the form of the mold is maintained as well as the form of the bone (Fig. 7). Since the surrounding flange, locators, and holes are part of the original mold, they are also incorporated into the pattern. Because any bone is molded in at least two sections, one mold is represented by at least two patterns.

The material used for the pattern itself is epoxy. As a casting medium, epoxy far surpasses any other in its strength and its ability to remain dimensionally stable. It is not only capable of making an almost perfect holes which extend through the entire mold. Later, when the fossil is removed and a cast is made from the completed mold, screws are inserted into these holes. Tightening the screws permits a controlled amount of pressure to be applied all around the mold during the casting process.

Once the plaster partline is completed and rods and locators are in place, three coats of molding rubber are brushed over the entire surface of the bone and flange. (In order to insure as much detail as possible, no surface coating is applied to the fossil bone.) After the rubber has cured, a hard plaster backing (the “keeper shell”) is poured. The first section of the mold is then complete and the temporary plasteric and plaster flange is broken away from the bone. The second side of the mold is made in an identical manner.

Making a New Mold

When a new mold is distorted or torn as a result of pattern making or in the production of casts, a new mold is made from the pattern. In this relatively simple process, silicone rubber is brushed on the pattern. After curing, the new flexible mold is removed. The locators and steel pins that were designed into the original mold make it possible for these new generations of molds to align exactly when taken from the cast.

Making a Pattern

Pattern making begins with the preparation of the mold; a wall made of dental wax is constructed around the face to prevent the epoxy and plaster used in making the pattern from leaking (Fig. 6b). The mold face is then covered with a 1/4-inch-thick layer of epoxy. Once this epoxy layer begins to cure, a layer of gypsum cement about 1 inch thick is poured over the epoxy to form an outer reinforcement. Thus the pattern is composed of a layer of epoxy, which captures the detail of the surface of the bone, backed with gypsum cement.

Technology of Casting
collections located in museums widely distributed throughout the world. Since a mold can produce more than one pattern, it is prudent, especially for important or noted fossils, to consider the fabrication of several patterns, to be stored in different places. Most of the early hominid fossils have been discovered in Africa and Asia, and it would be reasonable to establish repositories on these continents, as well as in Europe and Australia. Discussions are currently in progress with representatives of a number of museums and research institutions in various parts of the world for the establishment of other pattern storage locales.

It is also important to recognize that pattern manufacture and distribution is a major contribution that American scholars and institutions can make to colleagues in the Old World. No fossil hominids have ever been discovered in the New World. The development of storage repositories in different parts of the world can provide an important channel by which American anthropologists can contribute to the long-term future needs of the field of paleoanthropology.

Further, in the next few years, the production of exact replicas of likely to be extended from fossils to modern human remains. In Australia, for example, there is a possibility that most of the prehistoric and historic hominid bone remains discovered on that continent will be reinterred in the near future under court orders. Proposed legislation in the U.S. may also result in archaelogical remains being reburied after study. Without patterns to provide a record of these fossils and archaeological findings, these discoveries will be permanently lost to the scientific community.

Finally, we are currently investigating the ways by which the mold and pattern collection can be supplemented to store additional information about the fossil bones they preserve. Recent research in human evolution has emphasized the importance of the histological and other microscopic structural details observable on bone. Modern technology and materials used in the molding and pattern procedures permitted the preservation of these structures on pat-

The University Museum possesses the world’s largest collection of molds and patterns of hominid fossils. Thanks in part to the fame of the university to produce molds of fossil bones. He describes himself as a forecast bicyclist and is currently designing an undergraduate thesaurus in the University of Pennsylvania on the anatomy, mechanics, and biomechanics of this machine. Much of the molding and casting work described here has been supported by the National Science Foundation.

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Alan Mann is Associate Curator of Physical Anthropology at the University Museum. A paleoanthropologist, he has done fossil research in Africa, Asia, and Europe. He is the author of recent and general articles on the adaptation and behavior of our ancestors, and a monograph on early human evolution. Trained as a model maker in 1960 by the Warner-Geesen Foundation, he continues to travel to Europe to produce models of fossil bones.