Marsico Proposal

Enhancing Study of Human Evolution in the Undergraduate Curriculum

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This proposal requests funding in the amount of $36,053.10 to purchase new laboratory cast material for use in courses that deal with the study of human evolution. The cast material includes fossils of human ancestors and other extinct species, and comparative skeletal material from contemporary non-human primates, specifically the Great Apes.

The study of human evolution—paleoanthropology—is part of the following courses within undergraduate Foundations, Core, and Department curricula:

Ancient Worlds (AHUM)
Origin and Evolution of Life (NSM)
Anthropology: Global Perspectives (SOCS)
Science and Religion in Dialogue (CORE)
Human Nature (ANTH)
Human Origins and Evolution (ANTH)
Race, Sex, and Evolution (ANTH)
Evolution and Speciation (BIOL)

Funding of this project will provide world-class support for the teaching of human evolution at several key places within the general education curriculum. It will help to further Marsico initiatives in all three major categories: Experiential Learning, Intellectual Depth, and Numeracy. It will also better prepare our students to engage the long-standing and currently intensifying national debate about evolutionary theory's relevance for understanding humankind's history and place in nature.

Goals of the Project

Evolution is widely regarded by scientists as the central unifying concept of modern biology. Much the same can be said of its status within the social sciences (like anthropology) that take a deep-time perspective on human life. Yet for a variety of cultural and historical reasons—many relating to the chilling effect of the 1925 Scopes "Monkey Trial" on the teaching of evolution in public schools—the concept remains poorly understood. For many students the concept of evolution contradicts their most deeply held beliefs about human origins. The result is a mixed bag of reactions to the case for evolution, including resistance, guarded acceptance, indecision, and outright rejection. Even students who enthusiastically accept the case for evolution often get it wrong: they confuse long discredited transformational models of the evolutionary process (species change in response to environmental demands by volitional strivings to improve) with correct selectionist models (species change as a result of nature eliminating poorly adapted or unfit individuals).

Teaching human evolution thus presents a unique challenge. Meeting it requires constant pedagogical experimentation and abundant visual aids for illustrating the complexity of the phenomenon. **The central goal of this project is to improve student understanding of human evolution by combining new resources with new approaches to teaching.** The new resources are high quality casts of fossil skulls and post-cranial skeletons of human ancestors and non-human relatives. The new approaches (detailed below) depend upon acquisition of the cast material. The two will be brought together in ways that provide students with improved hands-on learning opportunities in the array of Foundations, Core, and Department courses identified above.

At present the anthropology department maintains a useful but eclectic collection of casts from several different suppliers. This material was purchased over the years using whatever university resources happened to be available, as well as my own personal funds. Most casts were bought as cheaply as possible, especially in the early years of my career at DU. The collection is thus of uneven quality, a situation that limits detailed study of individual specimens and also comparative study across the lot. Many of the cheaper casts—those made of hydrostone, a material that easily flakes and chips—are showing signs of wear and tear after years of heavy use in multiple sections of SOCS and NSM Foundations courses.

The attached "Paleoanthropology Lab" shows one way that the existing collection has been used within a Core Curriculum course. Specimens are numbered and students working in small groups employ standard morphological criteria for sorting specimens into taxonomic categories. Categories are then arranged into a phylogenetic tree. As much ambiguity as possible is built into the lab, so that students must use all their powers of critical thought to create and defend their categories and phylogenetic reconstructions. This basic lab has been modified for use in Foundations, Core, and Department courses. It will undergo another significant revision if this proposal is funded. In whatever way it's pitched, students enjoy the exercise once they get over their "foreign object" anxiety and begin seeing that clear patterns can be distilled from the data. The lab is a challenging and fun way to sharpen skills of classification and analysis. It also improves "visual literacy" to the extent that students must compare and contrast alternative phylogenetic trees of human ancestry, and draw one of their own.

The cast material for which funding is sought is made of high-quality, durable polyurethane resin from the best supplier on the market today, Bone Clones Osteological Reproductions of Canoga Park, California. The skull casts are also nice in that they indicate, by differential coloring, what parts of the skull were actually found and what parts were reconstructed by interpolation. Some of the new purchases will replace worn specimens, others will fill important gaps in the existing collection, and still others will open up whole new areas of study. The aim is to provide students with a coherent set of accurate, made-to-scale specimens that are suitable for comparative analysis. Bone Clones has offered a $2000 discount on the very expensive Neanderthal skeleton, a 10% discount on the rest of the order, and free shipping valued at $1000.

<u>**Process Goals**</u>

Acquisition of the fossil casts will allow us to teach new topics, and also to teach differently. Three main innovations will be permitted:

(1) For the first time we will be able to teach human evolution from the neck down. Up to now our labs have focused solely on cranial evolution. This is a crucial line of analysis and will always be central to our pedagogy because of the human cranium's clear illustration of evolutionary trends. However, heads aren't the only body parts that evolve. Perhaps the most important element of this proposal is the funding requested for post-cranial skeletons of living higher primates—the Great Apes—and selected human ancestors. This is important because paleoanthropological research has demonstrated that the key defining change in early human evolution was <u>not</u> brain expansion but rather selection for upright posture and terrestrial bipedality. Without post-cranial material our laboratory pedagogy reproduces old, Victorian-era biases about what distinguishes humans within nature (i.e., big brains). This project will allow the human evolution curriculum to catch up with paleoanthropological knowledge, and move it in more progressive and interesting directions.

(2) For the first time we will have specimens that we can systematically <u>measure</u> as an element of comparative work. Right now we ask students to make impressionistic evaluations of cast material based on relative size, form, shape, and presence/absence of skeletal features. With high quality specimens that preserve essential skeletal landmarks we will be able to have students quantify their observations. Species assignments in paleoanthropology are always accompanied by comparative data on cranial volume and the length/width of long bones, as well as a variety of mathematical indices that quantify skeletal shape. High quality cranial and post-cranial casts will allow students to replicate studies and independently evaluate results presented in technical journals. Polyurethane resin skulls, for example, will hold mustard seed or some other medium for measuring cranial volume without risk of breakage. A collection amenable to quantitative analysis will allow us to better evaluate the literature and conduct original studies of variation in ancestral human skeletal morphology.

Quantitative study will also allow us to consider questions of an epistemological nature about the meaning of numerical differences between constructed groupings. Within the lineage *Homo*, at what numerical threshold for cranial volume does one species end and another begin? 900 cubic centimeters? 950cc? 1000cc? Where does one draw the line, and why? When does a number capture an underlying existential reality, and when does it reify deep-seated investigator hopes and/or cultural prejudices about what our family tree should look like? These questions take on new immediacy in light of recent research proposing that all human ancestors belong to a single evolving lineage containing only one species at a time. With the debate between "lumpers" and "splitters" reheating we will need resources for conducting quantitative analysis in order to evaluate the arguments on both sides.

Finally, a "quantifiable" collection will allow a better understanding of intellectual history, specifically as it concerns studies of biological variation within *Homo sapiens*. Cranial volume served as a widely used indicator of race, and formed the primary basis for racial ranking, in 19th century American science. Topics around what Stephen Jay Gould described as the "mismeasure of man" can be more adequately covered with specimens that lend themselves to craniometric study. Thus, collection exercises aimed at boosting numerical literacy will help sharpen student skills of empirical, philosophical, and historical analysis.

(3) We will be able to put old specimens to novel pedagogical uses. Specifically, we will cannibalize the hydrostone and other inferior quality casts into a collection of cranial fragments (of braincase, jaw, etc.) and challenge students to type them via comparison with the known reference collection. This will more faithfully model the actual conditions and methods of paleoanthropological analysis, given that fragments are what we routinely deal with. It will also allow us to create lab exercises that take ambiguity—and the challenge of managing it via higher-order reasoning—to a whole new level. This will raise the bar for serious students of human skeletal biology and evolution, most likely in the context of upper-level Department and Core courses. But this kind of wrinkle can also be inserted into laboratory assignments for Foundations courses.

Outcome Goals

The outcome of this investment should be better student understanding of what we know about human evolution, why we know it, and why reasonable people of good faith believe in it. For the first time students will be exposed to the full range of significant cast material available for scientific study, and a much better comparative primate context in which to place it. As a result of this exposure students will be able to:

- *describe*, using the technical language of paleoanthropology, the range of variation in ancestral human form;
- *distinguish* between and *categorize* fossil humans at a hierarchy of taxonomic levels, including genus, species, and sub-species;
- *defend* taxonomic categorizations using both qualitative and quantitative criteria;
- *identify* the continuities and transitions that link the category of modern humans to ancestral species and to living non-human relatives;
- *recognize* where paleoanthropological knowledge is uncertain and/or deficient, and why;
- *construct* a phylogeny that effectively communicates both strong and weak linkages between

ancestral forms, as well as blind spots that can only be filled with new knowledge; and

- *explain* why their phylogenies look the way that they do.

The continuities and transitions mentioned above arguably form the most convincing line of evidence that human evolution has occurred. Whether agnostics and skeptics will allow themselves to be convinced by this evidence is, of course, another matter. The personal beliefs that mediate student learning on the subject of human evolution tend to be unyielding and fact-proof. Success will depend on what else is taught in any given course, and how it is taught. Success will also depend on respectfully engaging—rather than dismissing or disparaging—religious belief.

In a SOCS or NSM Foundations course where one of the goals is to impart the basics of human evolutionary history we can take a stab at measuring outcomes with pre-tests and post-tests that simultaneously model proper scientific thinking about the world. Pre-tests can ask students how they think evolution works, why they think some people believe in it and, most importantly, *what they would expect to see in the empirical record if evolution had occurred.* Post-tests can revisit these questions in light of what students have learned about human evolution by working with the context- and comparison-rich collection of teaching materials requested here. The key post-test question would be something like *Have your empirical expectations been met, and if so why, and if not, why not?* Even if no student minds are changed (although I'd expect at least a few agnostics and skeptics to be swayed) I'd consider it progress if we saw only minimal movement toward greater understanding of why other people accept human evolution as a scientific fact.

A sizeable literature exists on the topic of teaching and assessing student understanding of evolution (see the link provided above for an example and a bibliography). This literature has always guided our work on this campus, and it will continue to do so.

Budget Justification

The budget (see attached Bone Clones price quote) is entirely devoted to material purchases. What follows is the justification by key category, with Bone Clones catalogue number and description as a reference.

Living Primate Skulls (BC-1234). New material. This set of six skulls (human, orangutan, chimp, gorilla, gibbon, and bonobo) shows humankind's closest relatives in made-to-scale comparative context.

Pre-Human Skulls: BH-023 (*Proconsul africanus*), BH-024 (*Sivapithecus indicus*), BH-025 (*Aegyptopithecus zeuxis*). New material. The purpose of this set is to illustrate variety in the ancient stock of Miocene and Pliocene apes from which humans are descended.

Early Human Skulls: BH-001 (*Australopithecus afarensis*, composite), BH-21A (*Australopithecus afarensis*, "Lucy"). One new skull, one replacement skull. *Australopithecus afarensis* is notable for being the earliest human available in cast form.

Plio-Pleistocene Human Skulls: BH-003 (*Australopithecus robustus*), BH-006 (*Australopithecus boisei*, Turkana), BH-008 (*Australopithecus aethiopicus*), BH-015C (*Australopithecus boisei*, Olduvai).

These are replacements for hydrostone casts. They will allow much better comparison with recently purchased polyurethane casts of early members of the genus *Homo*. The coexistence of multiple species of at least two different genera of humans (*Australopithecus* and *Homo*) in East, South, and Central Africa makes the Plio-Pleistocene boundary a particularly interesting time period in human history. This is the material that creates the most problems for species definition and phylogenetic reconstruction in the lab setting. The differences are so nuanced that one needs particularly well-honed powers of observation and analytical skills to see them. Cultivating these powers and skills depends on having specimens that can be accurately and systematically measured.

Later Human Skulls: BH-005 (*Homo erectus*, China), BH-012 (*Homo ergaster*, Africa), BH-009 *Homo neanderthalensis*, La Chapelle, France), BH-019 (*Homo neanderthalensis*, La Ferrassie, France), BH-017 (*Homo sapiens*, Czech Republic), BC-093 (*Homo sapiens*, Germany), BH-022 (*Homo heidelbergensis*, Spain).

Some new, some replacement specimens. These are examples of "advanced" humans found across three continents. They include a couple of Neanderthals, the perennial enigma of paleoanthropological study. Are Neanderthals on the direct line leading to us, or are they an extinct side branch? The new *neanderthalensis* and *sapiens* acquisitions will combine with existing specimens to create a nice little subset for studying physical variation at the "high end" of the genus *Homo*. The skulls in this group will also be used in lessons on the nature and origin of human geographical "races". This is another hot button issue in paleoanthropology that draws enormous popular attention.

Complete Skeletons: SC-092 (modern human), SC-003 (modern chimp), SC-123 (modern bonobo), SC-028 (modern gorilla), SC-002 (modern orangutan), SC-047 (modern gibbon), SC-036 (*Australopithecus afarensis*), SC-012 (*Homo ergaster*), SC-019 (*Homo neanderthalensis*).

All new material. These specimens will allow, for the first time, analysis of human post-cranial variation and evolution. The six modern skeletons—like the skull set described above—provide a context for understanding humankind's place in the Primate order and an opportunity to discuss the complexities of evolution within the taxonomic family of higher primates.

The other three skeletons mark significant hinge points in human evolutionary history. The *afarensis* skeleton displays a hybrid ape/human post-cranial anatomy under a decidedly ape-like skull. It is a wonderful illustration of the "mosaic" nature of evolution, and a textbook example of a transitional form between the world of apes and the world of humans. *Homo ergaster* shows the first evidence for modern proportioning of human post-cranial anatomy under a braincase that is intermediate in size between modern ape and modern human. *Homo neanderthalensis* is crucial because it is arguably the single most controversial species in the human lineage in terms of phylogeny and behavior. The complete skeleton will allow direct evaluation of competing models of Neanderthal ancestry, cultural ability, and "racial" affinity. The cost is significantly higher than the other skeletons because the reconstruction has been years in the making using fossils from a variety of sources, with correspondingly high royalty costs. The specimen is the most complete and precise Neanderthal ever made, and Bone Clones is the only place in the world to get it.

Timeline

If this project is funded materials can be ordered straightaway and be ready for use in fall 2005. Over the summer of 2005 I will put together a complete inventory and write a "users guide" to the collection. Minimally, the guide will include (a) an overview of our current knowledge of human evolution, (b) research questions to which the collection is sensitive, (c) curriculum topics, (d) templates for classroom and laboratory exercises that can be tailored for Foundations, Core, and Department courses, and (e) a comprehensive bibliography of sources for teaching and assessing student understanding of human evolution.

Summary and Final Justification

Funding of this project will make a real difference in our faculty's ability to teach human evolutionary science. It will provide a world-class set of resources that few, if any, universities in the country will be able to match. It will put these resources directly into the hands of students. It will enhance—in a uniquely challenging and enjoyable way—experiential learning, critical thinking, and numerical and visual literacy.

Faculty in Biological Sciences and Religious Studies with whom I've taught—Mike Monahan, Jim Platt, and Greg Robbins—have indicated their strong support of this proposal and their interest in using the collection in their departmental courses. Use of the collection by colleagues in other disciplines and programs across the arts and sciences is limited only by our imaginations. Applications in cognitive neuroscience, environmental science, engineering and any other discipline dedicated to understanding relationships between organic and/or mechanical form, function, and context come immediately to mind. Darwin's theory also cast a long shadow across the humanities, including art and literature. Anywhere that Darwinian images and metaphors inform commentary on the human condition is a place where this collection of material can be used.

The collection will serve a number of educational purposes beyond undergraduate teaching. The accuracy and durability of polyurethane casts means that they are display quality, and thus can be used in campus museum gallery exhibits and other public presentations. Our existing collection has been used by the DU High School and other Denver area schools within the Reach Out DU program. Jim Platt is committed to using the collection in his NSF-funded summer institutes for middle school science teachers. I use the collection in my University College adult enrichment course on human evolutionary psychology. The educational bang for the buck spent to purchase this collection is, I think, enormous.

I mention these other educational purposes because they raise a final funding justification that relates to the University's mission to serve the public good. As indicated earlier, human evolution has been a major battleground in American culture wars since at least the 1925 Scopes Trial. The battle is intensifying today with the rise of supposed alternatives to evolutionism, specifically the movement known as "Intelligent Design". Emboldened by recent electoral victories and public opinion surveys, critics of evolutionism are pressing for new state and federal legislation that sanctions the teaching of antievolutionary theories in public school classrooms across the country. These theories have dubious if not altogether nonexistent scientific value. They threaten to further erode student and wider public understanding of human evolutionary history, and science generally. They harbor negative implications for public policy on the environment, medicine, and bioethics. As David Quammen notes in a November 2004 cover story in *National Geographic*, a proper understanding of evolution "is more crucial nowadays to human welfare than ever before". The university curriculum must be prepared to respond.

The 80th anniversary of the Scopes Trial is thus a fitting time to invest in the teaching and learning of human evolution on campus. The Marsico funding requested here will strengthen undergraduate education around natural history's central unifying concept. In so doing it will help to create a citizenry that's better prepared to engage the important public policy issues that have long haunted—and been haunted by—an evolutionary view of life.

Attachment

EXAMPLE OF PALEOANTHROPOLOGY LAB

CORE xxxx **NAME_____________________**

LABORATORY: PALEOANTHROPOLOGY

This lab is intended to sharpen your skills of classification, give you a general picture of basic trends in human evolution, and test your grasp of other issues in paleoanthropology. There is a laboratory phase and a homework phase.

Laboratory Phase: On the lab tables are 18 numbered skulls that cover the full range of human evolution between *Australopithecus afarensis* and modern *Homo sapiens.* Your task is to distinguish between the two main branches of human evolution (*Australopithecus* and *Homo*) and identify representatives of the various species of ancestors within each of these branches. A chimpanzee skull and a modern *Homo sapiens* skull are available for comparison; if you treat the chimp and the modern human as the two extreme end-points of the human evolutionary sequence, then all you have to do is fill in the "transitional" links between them.

Based on class discussion and your reading of our course textbook you should have some familiarity with the basic morphological criteria that are most useful for sorting fossil skulls into species. You should also know that defining species in the fossil record can be a messy exercise that involves "juggling" several different criteria simultaneously.

Homework Phase: The homework phase of the lab asks you to (III) construct a phylogeny of human evolution, (IV) evaluate alternative phylogenies of human evolution presented by experts, and (V) answer some other questions about the human evolutionary record **[Part V is not included here. These questions change depending on the particular course and the current state of paleoanthropological knowledge].**

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I. FOSSIL SKULLS: Please assign each numbered skull to one or another of the groups listed below, and briefly explain why you created the groups that you did--i.e., what morphological features distinguish each skull as a member of the group to which you assign it?

A. "Neanderthal"

B. "gracile" australopithecines (*A. africanus*):

C. Later Homo (*H. erectus*):

D. "robust" australopithecines (*A. robustus*; *A. boisei)*. NOTE: These have also been called *Paranthropus robustus* and *Paranthropus boisei*. For the purposes of this lab we will use the genus name *Australopithecus* to describe these fossils.

E. "Cro-Magnon" (Modern *H. sapiens*):

F. Early Homo (*H. habilis*):

G. *A. afarensis*

II. Some skulls are ambiguous in terms of their morphology, and thus can conceivably be placed in more than one species. Please identify the skulls that were most difficult for you to classify, and explain why they were difficult.

III. On the timeline below, please draw one possible phylogeny of human evolution by indicating on the graph where the 7 groups identified above (use the symbols A-G), AS WELL AS the Last Common Ancestor (LCA) to humans and chimps would fall. Locate your symbols at the origin points of the different species, and also indicate extinction points where appropriate. Be sure to indicate ancestral relationships by drawing lines connecting these 8 symbols.

IV. Consider the attached alternative phylogenetic reconstructions of human ancestry presented by experts in the field [**Not included here**]. Which of these reconstructions, in your view, best squares with existing, consensus knowledge of human evolution and your own experience examining the material in this lab?

V. Other Questions… [**Not included here. See note above**].