

Understanding Climate's Influence on Human Evolution

Climate and fossil records for the past eight million years suggest that some events in human and prehuman history—such as the evolution of new species or dispersals from Africa to other continents—coincided with substantial changes in African and Eurasian climate. This raises the intriguing possibility that environmental factors affected or controlled *Homo sapiens*' evolution. This National Research Council report proposes a coordinated, focused, and cross-disciplinary research program to improve understanding of how climate may have helped shape the species, and thereby shed light on the evolutionary forces that made humans distinctively human.

All living things interact with the earth system—the combinations of land, atmosphere, and oceans—that make up the planet's environment. As the earth system has changed over time, individual species have responded to these changes. In some cases, species have moved to new locations. In other cases, they have remained and adapted to the environmental changes, and sometimes this has led to the formation of new species. In some cases, species have become extinct.

In addition to responding to environmental factors, organisms also modify their environment, often in profound ways. Humans are no exception and have had a profound effect on the earth system. Humans also have an evolutionary history that reflects past environmental

challenges and opportunities. Although scientists have sought to understand the correlations between environmental and evolutionary events, the processes that underlie the connections between the two are still poorly known.

For example, there are continuing questions concerning the possible effect of regional climate

Hominins and Hominids

Throughout this report, the term *hominin* is used for any member of the evolutionary group of bipedal species most closely related to *Homo sapiens* that evolved following the split between humans and chimpanzees. It is a convenient way of referring to the evolutionary group that includes humans and their two-legged ancestors and evolutionary cousins. The term *hominid* includes all great apes, encompassing chimpanzees, gorillas, orangutans, and humans.



Australopithecus africanus, 2.5 million years old; *Homo rudolfensis*, 1.9 million years old;

Homo erectus, ~1 million years old; *Homo heidelbergensis*, ~350,000 years old; *Homo sapiens*, ~4,800 years old.

SOURCE: Courtesy of the Human Origins Program; photo credits include Chip Clark, Jim DiLoreto, Don Hurlbert, all of the Smithsonian Institution.

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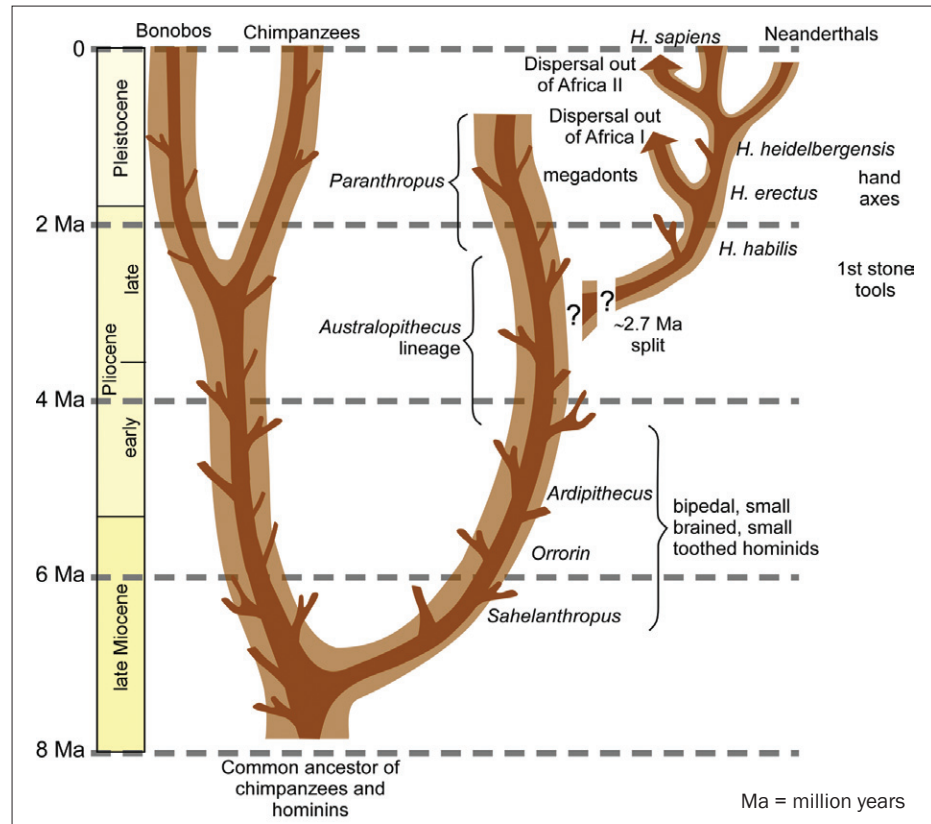
differences on the evolution of two separate hominin species—*Homo sapiens* and *Homo neanderthalensis*. The first appearance of *H. sapiens* occurred in Africa, as the earth entered a glacial period at about 190,000 years ago. Neanderthals, on the other hand, arose in Europe much earlier under the extremely cold conditions of the middle Pleistocene, and continued to exist there through rapidly changing climatic conditions. Each species has distinctive anatomical characteristics that have been inferred to be adaptations to climatic conditions—Neanderthals were shorter with more robust limb bones and shorter forearms, comparable to cold-adapted peoples of today (for example, the Inuit), whereas the modern human skeleton possesses longer and slenderer bones suggesting adaptations for warm environments. Eventually, *H. sapiens* expanded across the globe whereas Neanderthals became extinct around 28,000 years ago. Although the case for a climatic role in developing adaptive differences between these two species has received support, any definite causal relationships between climate and human anatomy remain to be determined.

These uncertainties also present opportunities. Transforming today's understanding of the human story requires an improved understanding of the timing of critical evolutionary and climatic events, an improved sampling of the fossil and archaeological evidence for critical intervals in human prehistory, and a dramatic change in the way in which earth scientists, climate scientists, and anthropologists work together to interpret this story.

The Fossil Record: An Incomplete History

Science has provided a general understanding of the timing of major events in human evolution (see Figure 1), but a paucity of fossils, particularly over the most interesting periods of rapid evolutionary change, has made it difficult to interpret what has influenced or controlled these events. New hominin fossil discoveries should enable a more precise understanding of the timing when species appeared and when they became extinct, so that comparisons can be made with the record of climatic changes at those times. An improved understanding of other fossils and fossil assemblages will also provide critical information

Figure 1. Highly simplified “family tree” illustrating the process of human evolution over the past eight million years; the many “twigs” branching off alone represent evolutionary “dead-ends.”



about evolutionary responses to environmental changes and invaluable information about the characteristics of the environments in which hominins evolved.

Climate History: Filling in the Gaps

Understanding the environmental characteristics of the areas where hominins evolved requires a range of climatic and other data—temperature, precipitation, seasonality, vegetation and land cover, and more. Although scientists and others have a general understanding of African and Eurasian climate history at a broad scale, this climate record generally lacks specifics and details about factors that potentially impacted how early humans lived, and in particular does not adequately reflect local differences in past climates. This lack of data limits understanding of the local climate characteristics that are so important for evaluating causative factors involved with hominin evolution. For example, improved climate records for specific regions could make it possible to evaluate how critical resources, especially water and vegetation, would have been distributed on the landscape during key intervals of human history.

A broad understanding of earth's history, and particularly climate history, has been gleaned from other fossils found in the same areas as hominin fossil discoveries and from analyses

of lake and ocean sediment cores. This material provides a wealth of information that can be used with the present generation of global climate models to understand paleoclimate characteristics and the factors that controlled past climates, particularly at continental and regional scales. At present, however, there are few sufficiently detailed paleoenvironmental records from areas close enough to the sites of hominin fossil discoveries.

Completing the Puzzle: Integrated Models

Once the fossil record has provided sufficiently detailed information about evolutionary and climatic changes, models and simulations can be used to understand the mechanisms underlying the effects of climate change on human evolution and to address detailed questions regarding the climate, water resources, and vegetation of hominin habitats. Models could be developed for the specific regions and specific key time periods that bear on potential connections between environmental changes and hominin evolution and dispersal. These models would help in understanding, for example, how changes in certain “boundary conditions” like sea-level or ocean gateway changes affected climate in specific regions. Models like this, however, can only be accurately tested by reference to actual paleoenvironmental data from Africa, Eurasia, and the surrounding oceans.

Strategies for Future Research

Although the exploration of human origins is inherently an international activity, large field-based research projects have been mostly conducted and funded along national lines, and broader partnerships and funding efforts are still relatively rare. International collaboration and cooperation focused on understanding the extent to which the earth system was a factor in human evolution offers the potential for applying the intellectual, organizational, and funding resources of a much wider community to an engrossing human question.



Figure 2. The drilling barge *Viphya* on Lake Malawi, East Africa, in 2005. Recovering deep cores from lakes near the sites of hominin fossil discoveries is a key element for understanding the record of local changes in climate and other environmental characteristics.

Several core areas of focus and action are needed to further this research:

- A major exploration initiative to locate new fossil sites and to broaden the geographic and temporal sampling of the fossil and archaeological record is recommended.
- A comprehensive, integrated scientific drilling program on land, in lakes, and in ocean basins surrounding the regions where hominins evolved is needed to address questions about changes in the earth system at a level of detail fine enough to characterize relatively short duration events and processes.
- A major investment is recommended in climate modeling experiments for the key time intervals and regions which are critical for understanding human evolution, focused on determining regional climate patterns and modelling at a more local scale the interactions between climate, ecosystems, and species population dynamics.

The coordination and management of a major international scientific program for climate and human evolution research would require a science advisory structure, with members representing the broader scientific community and with a broad vision of how these research components relate to



Figure 3. Replica of a 1.8 millennia *Paranthropus boisei* cranium found by Mary Leakey in 1959 at Olduvai Gorge, shown with a replica of a 1.2 millennia mandible of the same species from Peninj, Tanzania.

SOURCE: Image courtesy Human Origins Program, Smithsonian Institution.

each other, to foster communication among disciplinary groups, coordinate the implementation elements, and convey the science community's priorities to funding agencies.

The recommended research agenda offers an opportunity to make bold steps towards an understanding of the role played by past climates in the evolution of the human ancestral lineage.

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The National Academies appointed the above committee of experts to address the specific task requested by the National Science Foundation. The members volunteered their time for this activity; their report is peer-reviewed and the final product signed off by both the committee members and the National Academies. This report brief was prepared by the National Research Council based on the committee's report.



For more information, contact the Board on Earth Sciences and Resources at (202) 334-2744 or visit <http://nationalacademies.org/besr>. Copies of *Understanding Climate's Influence on Human Evolution* are available from the National Academies Press, 500 Fifth Street, NW, Washington, D.C. 20001; (800) 624-6242; www.nap.edu.

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