the government's solar energy program—the demonstration projects for solar heating. ERDA appealed to President Ford but, according to one observer, had the misfortune to argue its case during a week in which Ford was preoccupied with the Angolan crisis. In any case, the OMB position largely prevailed—a circumstance that apparently contributed substantially to the resignation of ERDA assistant administrator John Teem—and the proposed demonstration program, modest though it was, was drastically cut back.

The government program is having some effect—ERDA's work on photovoltaics and wind has stimulated some private investment. And quite apart from the government's program there appears to be a remarkable amount of momentum in solar thermal devices, wood burning stoves and boilers, and other components of a solar energy industry.

After 5 years of rapid but uneven development, solar energy is in need of reassessment. The present federal program has been as much the product of institutional happenstance and various technical predilections as it has been the product of coherent planning. In a broader perspective, the government policy under Republican administrations characterized solar energy as a long-term option comparable to fusion and the breeder, but in fact it has little in common with these potential leviathans. Solar technology is more diverse, and even the most difficult technologies, such as photovoltaics, may be closer to commercial realization. Many solar technologies already work, even though the best designs have not been found, and they are already facing the economic challenges that other long-range options have yet to confront. It is arguably time to reconsider solar priorities and ask whether the distribution of research resources among nuclear, fossil, and solar options reflects a rational policy.

ALLEN L. HAMMOND and
WILLIAM D. METZ

Human Evolution: Hominoids of the Miocene

As long as there have been fossils to study, investigators have devised scenarios to describe the history of the human lineage. This history has been pushed back further and further so that now many anthropologists are searching for traces of the human line among hominoids that lived as long as 14 million years ago. Recent fossil finds in Pakistan and eastern Europe are providing new evidence on which to base scenarios and are leading to new scenarios. Another consequence of these finds is that some investigators are beginning to question some previously accepted ideas about the diversity of species that existed at the time the human line evolved.

As they reexamine anthropological dogma in light of their most recent data some anthropologists are concluding that they have let certain scenarios get the better of them—that they have developed casts of mind that impede their attempts to understand the past. They are now trying to free themselves of these preconceived ideas of how hominoid evolution occurred (the superfamily Hominoidea includes the great apes, humans, and fossils resembling them) and are suggesting new interpretations of their data. Some anthropologists and geologists are concentrating on the influence of the environment on hominoid evolution. Another anthropologist suggests that birth-spacing patterns may have played a major role in this evolution. Still others are considering the most recent data and are using it to defend the classic view that tool use led to the distinction between human and ape ancestors.

One result of the recent finds of Miocene hominoids is the growing realization among anthropologists that these species were far more diverse than was previously realized. For example, David Pilbeam of Yale University and his associates found three species of these hominoids living in the same area of Pakistan during the Middle Miocene (from 17 to 7 million years ago). These species, known as *Sivapithecus, Ramapithecus*, and *Gigantopithecus*, are referred to by Pilbeam as the sivapithecids. He says that it is impossible to point to any one of these species as the human ancestor.

Pilbeam's analysis of his recent data from Pakistan contrasts with previous analyses of hominoid fossils. Previously, anthropologists tried to divide all extinct hominoids into two groups: those of human lineage and those of ape lineage. Many investigators further assumed that once the ape and human lineages arose from their common ancestor, these species gradually and continuously evolved toward their present-day forms.

The assumption that Miocene hominoids could be divided into two groups led anthropologists to the assumption that simple markers, such as thickness of tooth enamel, could be used to classify the species. Since present-day humans have thick enamel and present-day apes have thin enamel, hominoids with thin enamel were said to be of human lineage and those with thick enamel were said to be of ape lineage. These markers turned out to be not only uninformative but also misleading, Pilbeam says. Anthropologists developed erroneous notions of how evolution proceeded. The Miocene hominoids share features of both humans and apes and cannot be accommodated by the dichotomous classification scheme, according to Pilbeam.

New clues to the lives and fates of the early hominoids are arising from attempts by geologists and anthropologists to reconstruct the environments of these animals. Their results lead them to propose that the sivapithecids appeared during the Miocene when some heavily forested areas gave way to mixed environments consisting of dense forest, savanna woodlands, and more open areas. The sivapithecids differ substantially from the previously existing group of hominoids known as the dryopithecids. Dryopithecids lived both before and during the Miocene in heavily forested areas of Africa and Europe. It now seems likely that they never left these areas for more open environments. The sivapithecids, on the other hand, seem to have lived on the boundary between the forests and the open areas and to have exploited both.

Evidence that some of the Miocene hominoids lived in mixed environments is not extensive, but many anthropologists find it convincing. For example, Judith Harris Van Couvering of the University of Colorado points out that there are no counterexamples to this hypothesis. Sivapithecids were not present among assemblages of savanna-dwelling animal fossils found in China, Greece, and Iran. Nor were these hominoids found in the typical forested environments of Europe and Africa during the Miocene. The earliest well-dated *Ramapithecus* remains were found at Fort Ternan in Kenya, and they date to a time, about 14 million years ago, when this area changed from forest to a mixed environment.

Peter Andrews of the British Museum of Natural History and Van Couvering found that during the Early Miocene, the tropical rain forests now confined to western and central Africa extended far eastward and included Kenya. Toward the end of this period, volcanos formed in Kenya, in particular at what is now Fort Ternan. This volcano erupted about 15 million years ago. The slopes remained forested, but a savanna developed at the base of the mountain on top of the lava.

Pat Shipman of New York University recently reported results of an extensive study of the environment and fossil remains of animals that lived at Fort Ternan. She found that the state of preservation of the animals reflects the environments in which they lived. She has divided the animals into four major environmental groups: a savanna group, including elephants and giraffes; an aquatic group, which presumably lived in a nearby stream; a forest group, including squirrels and the forest-dwelling apes of the dryopithecine group; and a group that seems to have lived in an area between the forest and the savanna. This group of animals from the mixed environment includes *Ramapithecus*.

Although no other fossil assemblage has been as extensively analyzed as that from Fort Ternan, there is evidence that *Ramapithecus* lived in a mixed environment in Pakistan (along with other sivapithecids) and possibly also in Turkey during the Middle Miocene. Kay Behrensmeyer of the University of California at Santa Cruz recently worked with Pilbeam's group in the Potwar Plateau in Pakistan and analyzed the fossils found with the sivapithecids there. These hominoids lived about 9 million years ago and so are more recent than those at Fort Ternan.

According to Behrensmeyer, the environment of the Potwar Plateau at that time consisted of woodland and bush with patches of grassland but no dense forests. She found, for example, that forest animals such as arboreal primates and rodents are "conspicuously rare or absent from the fauna." In contrast, she found that the sivapithecids lived among small to medium-sized browsing and grazing ungulates that are typical of wooded and densely bushed areas, but not of forests.

An excellent *Ramapithecus* specimen from Turkey is a jawbone found by Ibrahim Tekkaya of the Mineral Research and Exploration Institute of Turkey in Ankara in 1973 and described in 1974. The area where it was found, about 40 miles northeast of Ankara, contains fossils of a mixed group of animals, Shipman says. Neither forest nor savanna animals dominate the collection, although both are present. These data, then, do not contradict the mixed-environment hypothesis. Although sivapithecids have also been found in Greece, Hungary, India, and possibly China (no one outside China has seen the specimens), the environments in which these animals lived have not been determined.

If it is true that sivapthecids appeared during the Miocene as forests gave way to mixed environments, what does this indicate about the course of evolution? Pilbeam, for one, believes that changes in feeding behavior, which are related to changes in habitat and ecological niche, may be a key to understanding the later stages of hominoid evolution.

Pilbeam stresses that none of the three species of Miocene hominoids found in Pakistan resembles either apes or humans living today. He points out that the sivapithecids all have jaws and cheek teeth similar to those of hominids that lived in East Africa about 4 million years ago. (Hominids include humans and their ancestors but not apes.) For example, the sivapithecids and the later hominids all have jaws and cheek teeth that are large in relation to their body sizes. In contrast, apes and forest monkeys have small cheek teeth and jaws. Moreover, the dryopithecids, which are believed by Pilbeam to include the ancestors of both the sivapithecids and the modern apes, had small cheek teeth and jaws. Anthropologists interpret these changes in teeth and jaws as evidence that the Miocene and later open-country hominids changed their diets as they moved out of the forests.

The change in environment from dense forests to mixtures of forests and more open country may have provided the necessary conditions for the existence of the sivapithecids. Stephen Jay Gould of Harvard University and Niles Eldridge of the American Museum of Natural History argue that new species arise "instantaneously" in geological time rather than evolve slowly from existing species. New species are most likely to arise from a small isolated population that lives at the periphery of the ancestral range, Gould says. The Miocene hominoids that lived in mixed environments could have evolved from isolated populations of the forest-dwelling dryopithecids in response to the changing environments in certain areas of Africa, eastern Europe, and Asia.

Movement of the Miocene hominoids into more open country may have affected their morphology and behavior, Pilbeam speculates. For example, the smaller species of this group may have become bipedal as a partial consequence of changes in the way they feed. Baboons, according to Michael Rose of Yale, are rarely bipedal but are so most frequently when they feed in the open. Behrensmeyer points out that the adaptation of the sivapithecids to a mixed environment may be a key to their competitive success. Maximum opportunities are provided to species that live on the boundary between two environments and exploit both, she says.

The Traditional View

This emphasis on changes in environment and feeding behavior contrasts with the traditional view of hominoid evolution. Proponents of this view say that the use of tools by human ancestors is what distinguished them from all other animals and enabled them to successfully compete with other animals for resources. The view is still held by many anthropologists, among them Milford Wolpoff of the University of Michigan.

Wolpoff is bothered by the facts that there was more than one species of hominoid living during the Miocene, that all of the sivapithecid species had large cheek teeth and jaws, and all are now said to have lived in mixed environments. What, then, determined which species died out, and which (if any) was a human ancestor? The answer to this question is as yet impossible to determine, Wolpoff says, because there is a gap in the fossil record between the Late Miocene (about 7 million years ago) and the period when hominids are first detected in eastern Africa (about 4 million years ago). Some of the later hominids in eastern Africa used tools, were bipedal, and are thought to be ancestors of humans. Anthropologists have no evidence that the Miocene hominoids used tools or were bipedal. Until more evidence is obtained indicating which Miocene hominoid was successful and why, Wolpoff sees no reason to discard the tool-use hypothesis.

Another explanation of how the sivapithecids became differentiated from the dryopithecids is that time between offspring, or birth-spacing, may have been the crucial factor. Owen Lovejoy at Kent State University has devised a birth-spacing explanation of hominoid differentiation as well as the success of sivapithecids in competing with other species. By successful he means that they occupied more area and existed in greater numbers than other species. His hypothesis arose from observations of

(Continued on page 294)

(Continued from page 245)

birth-spacing in living primate females, which, except for human females, only rarely become pregnant while they still have dependent offspring. Those whose offspring remain dependent for many years thus have long periods between births. This causes a problem for the present-day apes, which, Lovejoy says, are "relict species" occupying ecological niches in which they have little competition.

G. Teleki, E. Hunt, and J. Pfifferling of the University of Pennsylvania report that chimpanzees of Gombe National Park in Tanzania give birth on an average of once every 5.6 years. A consequence of this birth-spacing is that every female must live about 20 years in order for the population size to be stable. Old World monkeys, on the other hand, have life-spans roughly equal to those of the apes but have much shorter periods of infant and childhood development. Their average birth-spacings are 2 to 3 years. Most of the world is populated by monkeys rather than apes, Lovejoy points out, "even though apes are more intelligent."

Lovejoy speculates that the early hominoids gained a competitive advantage over other primates because they overcame this birth-spacing problem. He goes still further and says that more than the demography of the early hominoids was affected by this development. It may have led the hominoids to become bipedal, for example, in order to carry and care for several dependent offspring. Hominoids with several dependent offspring may have banded together and developed a social organization for mutual support and protection.

As always, anthropologists are hindered by a paucity of data when they try to formulate and evaluate their theories of human evolution. But as more and more Miocene hominoids are discovered, anthropologists are convinced that devising scenarios to explain evolution will lead them to a fuller understanding of the human past. Now that they are increasingly aware of the problem of developing preconceptions about what to expect from new finds, they believe the scenarios will be more useful. According to Glynn Isaac of the University of California at Berkeley, "Most people think that what is important is to have a series of alternative models that can be tested." As anthropologists begin to focus on the Miocene, such a series of models is being developed.

—GINA BARI KOLATA