

## Chapter 24. ORIGIN OF THE HUMAN ADAPTIVE PATTERN

*Contrast* the title of this book by Charles Darwin:

*The Descent of Man and Selection in Relation to Sex*

with this book by Jacob Bronowski:

*The Ascent of Man*

### I. Introduction

*Over the span of time from about 5.5 million BP until about 50,000 BP the hominid line evolved from something very like a chimpanzee to a biologically modern species essentially like ourselves.* The objectives of this chapter are to describe the basic differences between humans and our primate relatives, and to introduce you to the data and hypotheses that are available to explain the origin of the human species. In essence, we would like to be able to explain the hunting and gathering “revolution”—the emergence of a (presumably adaptive) pattern of human behavior that is rather distinctively different from that of apes. Even the simplest human societies we can study today are sharply different from the societies of our closest primate relatives. What sort of micro- and macro-evolutionary processes can we use to account for this development that began perhaps 6 million years ago?

*With quite some anatomical data on our ancestors, but barely any behavioral data, there is plenty of room to mythologize.* The work of the Leakey family, Donald Johanson, Tim White, Henry McHenry and many others have made the bones and stone tools of these people fairly well known. Roger Lewin (1987b) and Richard Klein (1989) survey the main findings. We have a fairly good outline of how our bodies evolved, although new fossil discoveries require major rewrites of parts of the story every year. There is much less certainty about soft parts and behavior. When did we lose our fur? When did estrous become cryptic? When did food sharing and male contributions to provisioning of females and offspring begin? When did male cooperation in hunting and warfare begin?

We don't know the answers to these questions. The history of ideas about human origins is fascinating because we are simultaneously so interested in the answer and free of constraints from the data. Scientists seem to have had an almost irresistible tendency to mythologize about our origins. Lewin reports on the work of paleontologist/historian of science Misa Landau who discovered in “scientific” accounts of human origins a structure remarkably like the heroic stories of mythology. Humans were set terrible trials (the shrinkage of tropical forest), which they met with risky quests (descent from the trees and explo-

ration of the new habitat). Ultimately, through great exertion and devotion to the principle of evolutionary advance, we triumphed and became modern people. Books like Bronowski's *The Ascent of Man* are recent, charming examples of such quaint stories in modern pseudoscientific dress. It is quite embarrassing that scientists have often written such stuff. We'll try to stick to the descent of humans not the Ascent of Man in these pages.

## **II. The Basic Adaptation of Modern Humans**

*The basic adaptation that differentiates modern humans from other primates is cooperative food foraging using cultural adaptations (technology).* The genetic resemblance between humans and the great apes is quite striking. However, there are substantial differences in terms of anatomy, behavior, and social organization. In the next few sections we will briefly examine the possible adaptive significance of these differences in an effort to understand how the human adaptive pattern—*foraging cooperatively using cultural adaptations*—evolved.

### **A. Humans Closely Resemble Great Apes**

*Using modern biochemical techniques it is now known that the human line must have split from the ape line only 6 million years or so ago.* Modern laboratory techniques such as sequencing proteins allow biochemists to estimate the average rate of change of proteins during the course of evolution. They do this by calibrating known divergences of lineages in the fossil record with protein differences. Humans are rather closely related to chimps and gorillas by these measures (Sarich, 1980). Modern biochemical methods are very accurate. They indicate that humans share a very high proportion of their genes with the African great apes (gorillas, chimps, and bonobos). This idea was once very controversial, but has gradually become well accepted as the evidence from different molecular evolution measurement techniques has accumulated.

*Biochemical evidence is more reliable than morphological evidence for trying to sort out which species are human ancestors and which are not.* There are many apes known from the Miocene period, ca 22 to 7 million years ago. Some fossil apes of this period have large grinding molar teeth rather like those of hominids. Paleontologists once were fairly confident that these were human ancestors. Now the biochemical evidence suggests that these were independent radiations of apes able to eat lots of coarse plant matter. It seems that measures of biochemical distance are not too well correlated with amounts of morphological difference. When evolution is rapid, form can change faster than gene sequences; the biochemical change is rather clock-like, giving good estimates of phylogenetic trees and times of divergence. The fossil record is very sparse, and hence unreliable when evo-

lution is rapid.

*Almost every element of human anatomy and behavior is at least foreshadowed by apes and monkeys.* Take tool use. Not too long ago, scholars would have confidently asserted that apes don't use tools. Now, chimpanzees are known to use a variety of tools, some requiring substantial preparation to use. There is quite suggestive evidence that chimpanzee tool use is based upon cultural traditions (McGrew, 1992). Elements of human forms of social organization are found among other animals, especially apes (Harcourt and de Wall, 1992; Maryanski and Turner, 1992). Some bonobos (pigmy chimpanzees) can apparently comprehend human language to a surprisingly sophisticated standard (Savage-Rumbaugh, et al, 1993). To be completely accurate, the following lists of differences would have to be qualified with a rather technical discussion of the exact capabilities of apes in comparison to humans. This is as it should be. 6 million years is a fairly short period of time, and it stands to reason that human capabilities will have evolved by shaping, modifying, and exaggerating capabilities present in the last common ancestor we shared with the apes, most probably an animal not very different from the living chimpanzees and bonobos.

### ***B. Anatomical/Physiological Differences***

There are six particularly important anatomical/physiological differences between humans and other apes. Each of these differences has important adaptive consequences:

1. *Humans are bipedal.* This frees the hands from locomotion, facilitating an increase in manual skills, tool use, and carrying things.

2. *Humans mature very slowly* and have a long life. This enhances enculturation via vertical transmission; a long childhood allows for lots of opportunities for parents to teach their children cultural knowledge. The disadvantage is that slow maturation lowers potential reproductive rates.

3. Humans have *small canine teeth and large flat cheek teeth.* We use tools to substitute for canines. Our big cheek teeth are well-suited for eating coarse vegetable foods, such as seeds and roots instead of fruit. This is a dietary *generalization* rather than a specialization. Small canines may also be related to relatively low levels of intra-group aggression in human societies—the long canines of primates are mostly used for displays and acts of within-group aggression.

4. Humans have very *large brains* which enhance/facilitate the storage of cultural information, calculating abilities, rapid evolution via culture, and flexible behavior. The disadvantage is that large brains are energetically expensive and fragile. Perhaps equally important, large heads cause birthing problems<sup>1</sup>; thus, brain size comes under stabilizing

natural selection (Chapter 9). This is an example of how cultural evolution may not always favor genetic fitness.

5. Humans also have *cryptic estrous and perennial sexual activity*. This may be important in that it provides the psychological motivation for pair bonding. In turn, the tendency to pair bond tends to protect genetic fitness from divergent cultural evolution by making sex pleasurable and the rhythm method unreliable. If you can't immediately see the disadvantages of cryptic estrous and perennial sexual activity, see any soap opera (Burley, 1979).

6. Unlike other apes, humans have a *two part vocal tract* that makes it possible to speak complex languages. It also makes the likelihood of choking to death fairly high (Lieberman, 1975).

### ***C. Psychological-Behavioral Differences (Possible Adaptive Significance)***

There are also some clear psychological-behavioral differences between humans and the other apes, that may also have evolutionary consequences for cultural transmission.

1. *Low intra-group aggression* enables co-operation and division of labor—males can work together instead of fighting. Females gain husbands who make a major economic contribution to the rearing of offspring. Males lose the ability to compete freely for mates; and females lose the ability to observe male fitness displayed clearly in fights and choose to mate with the winner.

2. *Humans transmit subsistence strategies and ideas about social organization by means of cultural traditions*. We have discussed the advantages and disadvantages of this difference at length in Chapters 11 and 12, and elsewhere.

3. *Language and other symbolic capacities* such as art, dance, and ritual characterize humans. These capacities facilitate communication, provide an organizing memory with which to store culture, and make us more efficient at discerning ingroup/outgroup distinctions. The key disadvantages to this ability may be the results of runaway and handicap cultural processes involving indirect bias.

### ***D. Social-Organizational Differences (Possible Adaptive Significance)***

Finally we list the primary social-organizational difference between humans and the other apes, and their consequences for evolutionary processes.

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1. In other words under natural selection individuals with large but not extra-large brains will come to predominate in the population. Under cultural selection alone ever increasing brain size is favored.

1. Humans live in *large well-organized groups* that enable them to acquire and defend resources cooperatively. The disadvantages that arise from living in large groups such as these are cheating and similar public goods problems, as discussed in Chapters 21 and 22.

2. By *sharing resources* a division of labor can be reached, between mates, parents and offspring, and other kin. This was probably especially important for hunting large game, and for sharing resources in times of drought, defeat in war, etc. Hunter-gatherer bands and ethnolinguistic units seem to act like insurance pools, enabling people to adopt strategies with high average rewards, but high variation in success. An active, able hunter will often go many days without making a significant kill, but he can depend upon meat for himself and his family because other hunters will get lucky and share the meat from their kills. When gathering resources fail in one band's territory, they will usually receive permission to use the territories of coethnic neighbors. Such arrangements increase work efficiencies but the disadvantages are the same as for #1 above.

3. *Home-base settlement patterns* facilitate co-operative resource acquisition, division of labor, and sharing. They also permit environmental modifications like house building. Perhaps the greatest disadvantage of this settlement pattern is that it is unsanitary, and can be dangerous if enemies know the location of one's residence.

### ***E. Summary***

Modern humans are quite odd in comparison with other mammals. While no single feature is particularly striking by itself, all of them together present quite an evolutionary leap. The most important differences are presumably our large brains, extreme dependence on cultural traditions, and large scale cooperation. The question we now want to address is how evolutionary processes caused these differences to arise.

### III. Basic Paleontological Data

#### A. Basic Macroevolutionary Pattern

Table 24-1. An Overview of the Basic Human Macroevolutionary Pattern

Time Scale (years bp)	20x10 <sup>6</sup>	3.3x10 <sup>6</sup>	2x10 <sup>6</sup>	1x10 <sup>6</sup>		0.15x10 <sup>6</sup>	0.05x10 <sup>6</sup>
Organisms	Miocene apes	<i>Australopithecus afarensis</i> , <i>affricanus</i>	<i>Homo habilis</i>	<i>Homo erectus</i>	Archaic <i>Homo sapiens</i>	<i>Homo sapiens neanderthalensis</i>	<i>Homo sapiens sapiens</i>
Basic Anatomical Characteristics	small brains (basic apes?)	bipedal, small brain, big sex dimorphism, big cheek teeth	<i>Homo</i> increasing brain size, modest sex dimorphism, declining tooth size			big brains	two-part vocal tract (basic modern humans)
Tool Traditions	?	small-scale use of temporary tools like <i>Pan</i> (chimps)	Oldowan pebble tools	Acheulean basic flake		Mousterian medium fancy	very fancy tools
Adaptations	?	tropical savannah/dry woodland. Misc. forager?	tropical savannah/dry woodland. Misc. forager?	tropical savannah/sub-tropical forager/hunter.		tropical-subboretic (cold climate) hunter-forager.	tropical-arctic hunter-forager

The basic human macroevolutionary pattern (Table 24-1) shows a discrete or mosaic-like accumulation of traits. As far as can be judged from the fossil record, the evolution of one part of the trait complex is more or less complete before others even start. It appears that the complex suite of human adaptive traits developed in pieces—much as one develops a mosaic pattern by laying down first one piece, then another. For example, bipedality developed before big brains.

Art and possibly even good language only appeared very late, long after brains were quite large. Lieberman and coworkers (1975) have studied the physics of speaking and tried to reconstruct the vocal tracts of fossil hominids from the morphology of the bottom of the skull. He argues that even Neanderthals, who were replaced by modern humans in Europe only about 40,000 years ago, could not speak, at least not anywhere near so well as modern people<sup>2</sup>. Marshak (1976) notes that, until the advent of modern humans, evidence for art is very scarce in the archaeological record, and that the art that has been found is

2. This is highly controversial.

quite modest. Perhaps the extensive use of symbols is a very late development in human history. Isaac (1981) makes the same point about the arbitrary imposition of pattern on tools, and the development of non-functional stylistic variation from site to site in tools. Until very late in the record, tool traditions lasted a long time, were not very fancy, and did not vary much from place to place. As anatomically modern people arrived, tools got much fancier and started evolving stylistically at a much more rapid pace. This event was probably accompanied by a revolution in social organization; perhaps the symbolically marked ethnic group level of social organization arose at this time, but we have essentially no information about the social organization of Neanderthallers and earlier hominids. The arrival of anatomically modern, symbol using humans in Europe about 35,000 BP is called the Upper Paleolithic Transition. The moderns replaced the Neanderthallers there and caused an abrupt modernization that was complete by about 33,000 BP. On the other hand, skeletally modern people are known from South Africa and the Middle East dating back to about 100,000 BP, but they were using Mousterian tool kits much like those of the European Neanderthals. Just when and where modern symbol-rich behavior patterns arose is currently unknown. The transitionally modern people are still hiding from archaeologists!

*Early adaptations may have prepared our neuro-physiological system for highly complex cerebral tasks.* In his book *The Cerebral Symphony* (1990), neurophysiologist William Calvin argues that the neural machinery that initially evolved because of selection for the ability to throw now enables us to use language, plan for events far in the future, and make music. Calvin argues that ballistic motions such as throwing a rock or stick, hammering, or kicking are extremely hard to perform because they occur too quickly for us to make corrections as we progress from wind-up, propulsion, release, and follow-through. For example, when you carry a full cup of hot coffee, your hands are constantly making corrections based upon information from your eyes and inner ear: “Wups! A little to the left. Steady. Look out! Level, level; that’s it. Now set it down. Don’t slop!...” When you throw something slowly, there is still time for a bit of correction as the process unfolds. However, slow throwing lacks both the distance and speed that will put a prehistoric rabbit over the cooking fire for dinner. Thus, over time, Calvin thinks that natural selection would have favored those who were more able to throw accurately—or hit a flint nodule accurately to make spear points.

The neurological machinery needed to accomplish this task is quite complex. Once humans evolved the machinery necessary for ballistic motion, however, a whole new set of behavioral options became possible. High speed ballistic motions require us to store a large and complex set of movement instructions in our brains before the motion begins. Instead

of correcting our movement as we proceed as is done carrying a cup of coffee, we have to have all the instructions for a ballistic motion entered in our cerebral computer before we initiate the throw. Essentially, Calvin argues that when we are not throwing, we can use the same neurological capacity that allows us to store ballistic instructions to manage other activities requiring large sets of complex instructions such as playing a Beethoven concerto or planning a college education. This is the ability that allows *real* conversation where you are simultaneously thinking about what someone else is saying, what you are going to say in response, and what you are saying now.

In short, the evolutionary consequences of preadaptations such as those that coordinate our symbolic capacities can be profound. The fact that traits designed for one purpose may hundreds of thousands of years later kick in as useful for an entirely different task may contribute, in part, to the mosaic pattern of human evolution.

### ***B. Relationship Between Cultural Complexity and Environmental Variation***

*Change in cultural complexity does not appear to have been smooth, and its relationship with environmental shifts is inconsistent.* Figure 24-1a illustrates changes in cultural complexity found in the archeological record. Although the significance of the pattern is presently obscure, it does not seem as though the data are consistent with a smooth acceleration. During the Acheulean period<sup>3</sup> of nearly 1 million years, culture changed very little to judge from stone tool form. A smoother pattern of technical development began around 100,000 years ago with the appearance of *Homo sapiens*, but the association of this development with any environmental change is presently unsupported. Conversely figure 24-1b illustrates the dramatic shift in climatic fluctuation associated with the onset of the Pleistocene epoch ~ 1.6 million years ago. Notice how *Homo* emerges about the same time as the change to the Pleistocene climate.

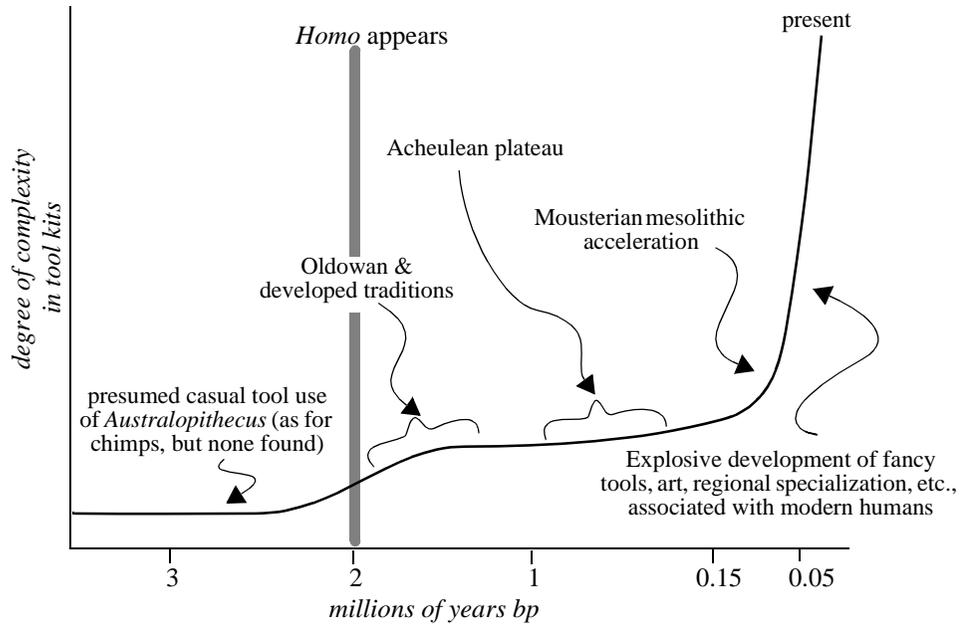
*Note that we cannot really say too much about the development of many elements of the modern human adaptive complex.* Did the early Pleistocene “humans” hunt or merely scavenge game? This is a controversial area where some bits of evidence can be developed based on bone assemblages, evidence from cut-marks, etc. (e.g., Behrensmeier et al., 1986). When did humans start to share food, live in base camps, lose indicators of ovulation, and so forth? Isaac and others interpret some early tool concentrations as home bases, but this interpretation has recently become quite controversial. The social organization and other behaviors of early hominids may have been very different from that of modern people. At what point in hominid evolution would we really want to call these creatures hu-

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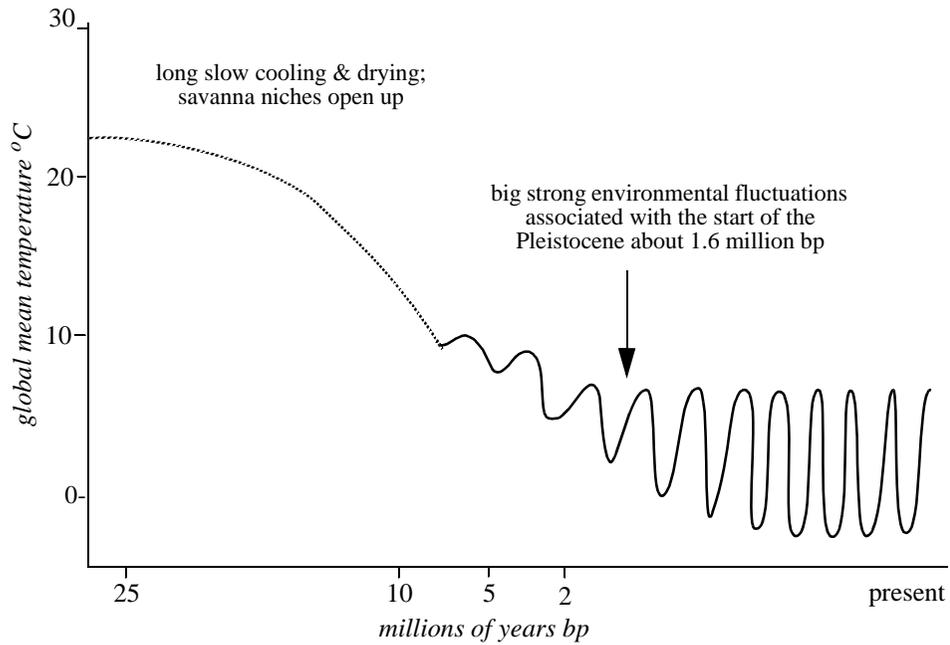
3. roughly corresponding to *Homo erectus* level humans, although perhaps also with biologically more advanced forms as well

Figure 25-1. Changes in the degree of cultural complexity among hominids and their ancestors appear to correlate with changes in the level of climatic fluctuation. Note that the time line in graph b) is strongly exaggerated for illustrative purposes.

**a) Cultural Complexity**



**b) Environmental Change**



man? This depends much more on behavior than on anatomy. Humans sometimes attempt to raise apes as if they were children and incorporate them into human families. This always fails because apes cannot be sufficiently socialized. As they become adult they become much too rough and wild to live free in a human household. It is presently impossible to say at just what point in human evolution we would feel comfortable with one of these ancestors of ours as a room-mate!

## IV. Types of Hypotheses

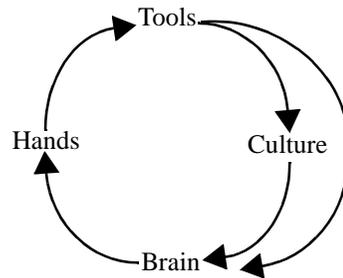
### A. *Internalist Hypotheses:*

*Internalist hypotheses, of which there are many, usually envision some sort of adaptive breakthrough, after which a positive feedback of some type sends hominids off on a relatively smooth evolutionary trajectory towards modern humans.* Thus, some sort of chance evolutionary event set up the necessary preadaptation, after which the environment for each stage in the trajectory was susceptible to “deterioration” by competition with types that had the more perfected version of the human adaptive complex (e.g., each improvement in weapons technology reduced game densities and made neighbors more dangerous; selection continued to favor better weapons makers and users).

*Upright posture frees hand, and free hands are seen as the key preadaptation to subsequent social evolution.* Tobias (1981) argued that as the climate cooled and dried our quadrupedal ancestors moved out onto the expanding savanna, because savanna living favored bipedal locomotion. There are various speculations on why bipedal posture evolved. Perhaps early hominids had to carry primitive weapons to protect themselves on the open plains, perhaps they used hands to harvest seeds, or to carry resources back to a home base. Bipedal walking may also simply be the most direct route to an efficient gait for an arboreal lineage evolving to exploit the savanna. Apes are quite inefficient walkers, but humans are about as efficient as typical quadrupeds (McHenry, 1982). This adaptation set up a positive feedback process that drew out the other parts of the trait complex -- a smoothly accelerating evolutionary trajectory.

*Although hypotheses such as these make good sense, they have serious problems.* First, hypotheses that depend too much on internal feedbacks (there are, for example, scenarios linking bipedal gait to pairbonding to monogamy to extended offspring dependence to the division of labor, etc. (see also figure 24-2) have real difficulty in accounting for the mosaicism of the paleontological record. Why did our major traits (Table 24-1, see also Figure 24-3) come in bits and bobs, and not in the kind of smooth trajectory envisaged by proponents of internalist hypotheses? The internalists would respond by proposing a

Figure 25-2. An example of the role played by positive feedback processes in progressivist explanations of the evolution of human culture (from Washburn, 1960).



“rough adaptive topography” (see Chapter 23), such that innovations were retarded by deep chasms that took a few hundred thousand to a couple of a million years for adaptations to evolve around.

Second, these hypotheses don’t account for the specifics of the hominid adaptive break-throughs. Why did hominids only start having large brains ca. 2 and not 5-15 million years ago? Why did the breakthroughs permitting cultural adaptations occur only in the hominid lineage? Why did they occur among our African ancestors, and not elsewhere in the world? Internalist hypotheses are poor at answering these “big questions”.

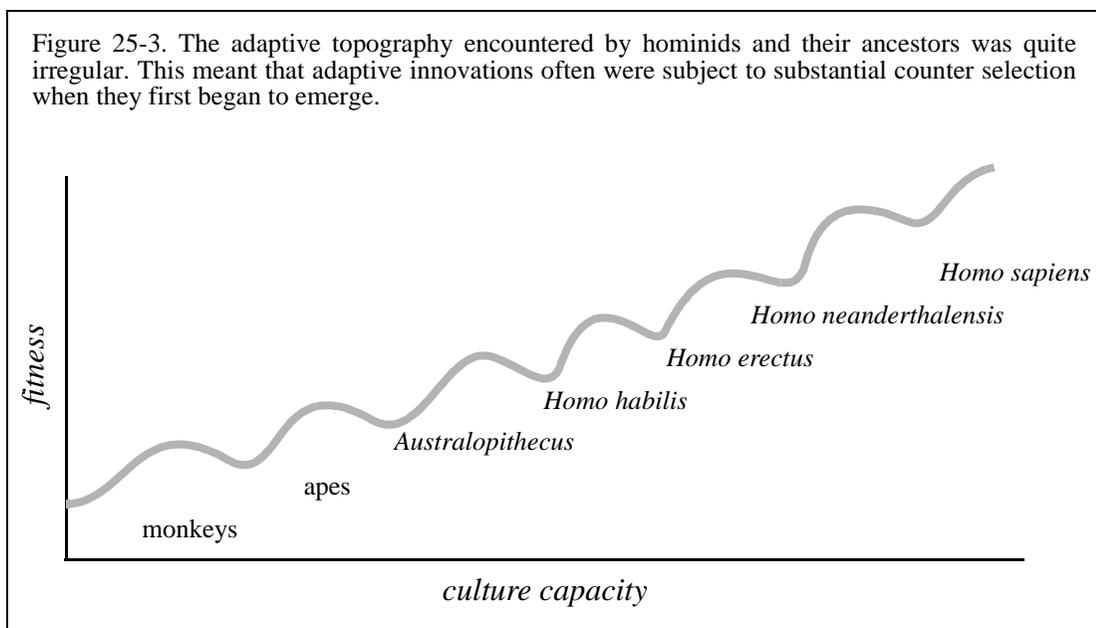
Third, they rely often implicitly on the notion that somehow hominids were preordained to move inexorably up to our currently dominant position in relation to most, if not all others animal life forms<sup>4</sup>. As evolutionist we must always be suspicious of “explanations” that rely on “causes” that are more ideological than scientific.

In sum, while internalists hypotheses are particularly useful in generating explanations for fine scale historical changes (see Chapters 26 and 27) their application to large scale events (such as hominid evolution and the neolithic revolution (Chapter 25) is problematic. This is because they are often strongly tainted with the view “onward and upward to Nature’s crowning jewel - Man”, and because external influences on the timing and specifics of evolutionary change receive scant attention.

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4. Daily we drive species to extinction, encroach on the remaining habitat of others, and spend millions of dollars on controlling pathogenic organisms.

Figure 25-3. The adaptive topography encountered by hominids and their ancestors was quite irregular. This meant that adaptive innovations often were subject to substantial counter selection when they first began to emerge.



### B. Externalist Hypotheses

*Externalist hypotheses attempt to explain the human trait complex as an ordinary adaptation brought about by a change in environment*<sup>5</sup>. The most obvious environmental correlates are the gradual drying and cooling of the earth's climates since the Miocene. The Miocene epoch began 25 million years ago as Antarctica drifted over the South Pole and glaciations began. The Miocene was a period of revolution in mammalian adaptations generally, as animals adapted to cooler and more variable climates (see the graph of climate variation in Appendix 24A) and more open, less forested habitats arose. These animals included a number of apes with resemblances to hominids. Mammals also, on average, got brainier during this period. According to Jerison (1973), early tertiary mammals showed no signs of increase in brain size over Mesozoic mammals. We all know about the stupidity (or at least relatively small brain size) of the dinosaurs, the most famous Mesozoic animals. All animals remained pretty stupid until the last 25 million years or so, when a fair proportion of them began to develop conspicuously large neocortexes.

*Then a new spurt in brain size came with the onset of the Pleistocene glaciations.* Beginning about 2 million years ago, glaciation began in the Northern Hemisphere too, and the pattern of conspicuous fluctuations of climate began, or got stronger. As the Pleistocene

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5. Recall from Chapter 24 that externalist hypotheses hold that most populations are usually very well adapted. However, populations are seldom, if ever, perfectly adapted because of environmental fluctuation; i.e., evolutionary processes are tracking a moving environmental target.

advanced, the pattern of fluctuations changed from shorter- to longer-term (see Appendix 24A). Perhaps hominid adaptations are just part of the general mammalian response to climatic change.

*If the patterns of variation in the climate record sketched in the appendix are correct, more brains to cope with the demands of more learning and eventually culture may be a response to an increasingly variable climate<sup>6</sup> (look back to Chapters 11 and 12 for the rationale behind this). In this view, small simple brains do not so much indicate “primitive” animals, as simple, invariant climates that do not put much of a premium on costly processes like individual and social learning. The increasing variability of climate looks like the right kind of environmental change to favor increasingly sophisticated individual and social learning abilities.*

*This externalist hypothesis has become the major alternative to internalist feedback hypotheses for the origins of the hominids. It seems more reasonable to look for a direct adaptive response to environmental change, not just an accidental trigger + positive feedback story, to explain each mosaic bit in the human adaptive complex. For example, a bipedal gait might have arisen in response to the spread of savannas. Just what primates may have been doing on the savanna is still a bit puzzling. Hunting or scavenging animal carcasses has been suggested, but the large cheek teeth of *Australopithecus* suggest that they were initially foraging for bulbs, seeds, and other relatively high-quality plant resources. This would have been a marginal adaptation to the savanna, as forests are probably a better source of this kind of plant resource. The bipedal gait would have allowed large territories to be gleaned for these resources. Then later, as the climate deteriorated still further and began to fluctuate more strongly (at the beginning of the Pleistocene 1.6 million years ago), culture capacities and the employment of hands to manipulate technology may have arisen (see Lewin, 1987a).*

*The externalist hypothesis nevertheless fails to account for several important details. For example, there is not much correlation between climatic shifts and the evolutionary **details** such as the Acheulean Plateau, and the recent explosion of first biological then cultural evolution. With the availability of new ocean core data yielding information on the paleoclimate, externalist hypotheses are likely to be strongly refined (or perhaps rejected?) in the near future.*

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6. These climatic fluctuations affected the whole world, though the details differ in each location. The tropics were affected by cycles of aridity as the temperate and arctic regions were exposed to cycles of glaciation and cold climates.

### ***C. Non-Adaptive Diversification***

*Does the evolution of hominids show any signs of generating non-adaptive variation?* Humans only evolved once, in Africa, despite the existence of similar habitats on all the continents. The *Australopithecus* niche was filled on the other land masses before the migration of *Homo*, with a combination of other animals, but no other group converged on our lineage. Why didn't this happen? Some element of historical accident must have been important on a fairly long time scale. Either the apes of Africa were the only animals with the preadaptations to become culture-bearing bipeds<sup>7</sup>. Or they were the only ones to break down a previously adapted complex of traits, or the African environment was the only one that offered opportunities to move from local peak to local peak (e.g., figure 24-3), or something else. If some evolutionary accident had befallen the Australopithecines, probably humans would never have arisen at all. Thus, to some extent at least, each major biogeographic region seems to be a unique evolutionary experiment with at least some non-convergent differences.

## **V. Conclusion**

Neither extreme externalism nor extreme internalism seem to fit the existing human data perfectly. Recalling that the differences between these two hypotheses are all a matter of the time scale and mode of innovation limitation (see Chapter 23), we are free to adjust time scales, and mix these hypotheses in other ways. On the grand scale, it seems that an externalist hypothesis fits quite well; humans are basically a weedy generalist well adapted to take advantage of the rapidly changing Pleistocene climate. On a smaller time scale, some form of internalism seems required to account for the increases of culture capacity within the Pleistocene period. Given that only one lineage responded to the climatic deterioration with a spectacular increase in culture capacity (and that one was ultimately very successful and able to spread to all continents), convergence was clearly imperfect, indicating a role for non-adaptive variation in evolutionary processes. If early humans were at some sort of adaptive peak, lineages from the New World and Australia showed no signs of converging on it. Hominids remained an African lineage for a long time before they even spread to Eurasia, but once they arrived they were successful. An element of historical accident seems well demonstrated in this evolutionary record.

*The data still allow much room for interpretation.* Every major new hominid fossil discovery seems to generate a significant reevaluation of hypotheses. Perhaps we will never

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7. William Calvin's discussion of the neuro-physiological complex permitting complex cognitive operations was an example of a "preadaptation". (Stephen Gould calls them exaptations).

get an uncontroversial explanation of this problem. On the other hand, our knowledge of the fossil and climatic record is still steadily improving, and tests of hypotheses are possible; at least the *range* of sensible hypotheses might eventually be narrowed. In the meantime, depending on your taste, this problem is either fun to think about or quite frustrating.

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***For good reads by the bone guys see:***

Johanson, D. and M. Edey. 1981. *Lucy, The Beginnings of Humankind*. New York: Simon & Schuster

Leakey, R. E. and R. Lewin. 1977. *Origins*. New York: Dutton.

## **Appendix 24-A: Note on the Climatic Record**

A number of different methods are used to reconstruct past climates. They fall into three classes, physical methods, biological methods, and human historical documents.

An example of physical methods is the use of oxygen isotope ratios. Most oxygen on earth is O<sup>16</sup>, the isotope with an atomic weight of 16. Some, however, is the heavier O<sup>18</sup> isotope. For most purposes the isotopes are essentially identical. However, water molecules containing O<sup>18</sup> are heavier enough than O<sup>16</sup> water to have a slightly lower evaporation rate. When large amounts of ice accumulate during ice ages, the water in the ice tends to be relatively depleted in O<sup>18</sup>, whereas the ocean waters become somewhat richer in <sup>18</sup>O. By using a mass spectrometer to measure O<sup>18</sup>/O<sup>16</sup> ratios in samples from ice or bottom sediment cores, the fluctuations from glacial to interglacial conditions can be estimated. One of the longest deep sea core O<sup>18</sup>/O<sup>16</sup> records is illustrated on the attached figure.

Biological indicators use the idea that the ranges or behavior of organisms change with temperature or other features of climate. The pollen record from Macedonia in the figure for the next chapter is an example, as is the foraminifera abundance curve attached. (Foraminifera are marine amoebas that live in little calcium carbonate shells. The shells are abundant in marine sediments, and so they have been favorites for both physical and biological measurements of climate change.) Tree-ring width estimation—rings in the Western U.S. are closely correlated with rainfall in some localities—is another example.

Human historical records include accounts of famines, freezes, and other unusual events, and a few fairly long runs of data on dates of wine harvests and the like. The instrument record only began even in crude form only in the 17th Century. Lamb (1977) discusses these early records in some detail.

Figures 24A-1 through 24A-3 illustrate Pleistocene environmental fluctuations. Figure 24A-1a gives estimates of historical temperature trends based upon data from a number of sources. Figure 24A-1b provides similar data based upon tree ring data. Figure 24A-2a

presents data from deep sea cores and figure 24A-2b presents similar data based upon ice core samples. Figure 24A-3 from Lamb (1977) shows analysis of an equatorial deep sea core covering the last 2 million years.

Figure 24A-1.

(A) "Generalized surface temperature changes of the earth over its geological history. Only relative departures from today's conditions are suggested; particularly for Precambrian times (copied from Schneider & Londer (1984:15)."

(B) "One of the best methods of reconstructing paleoclimatic conditions is to compare the proxy evidence from independent lines of evidence. This figure compares tree ring widths in the White Mountains of California against an analysis of mountain glacier expansions and contractions in the Holocene as inferred from debris left behind from these events (copied from Schneider & Londer (1984:104)."

(A)

(B)

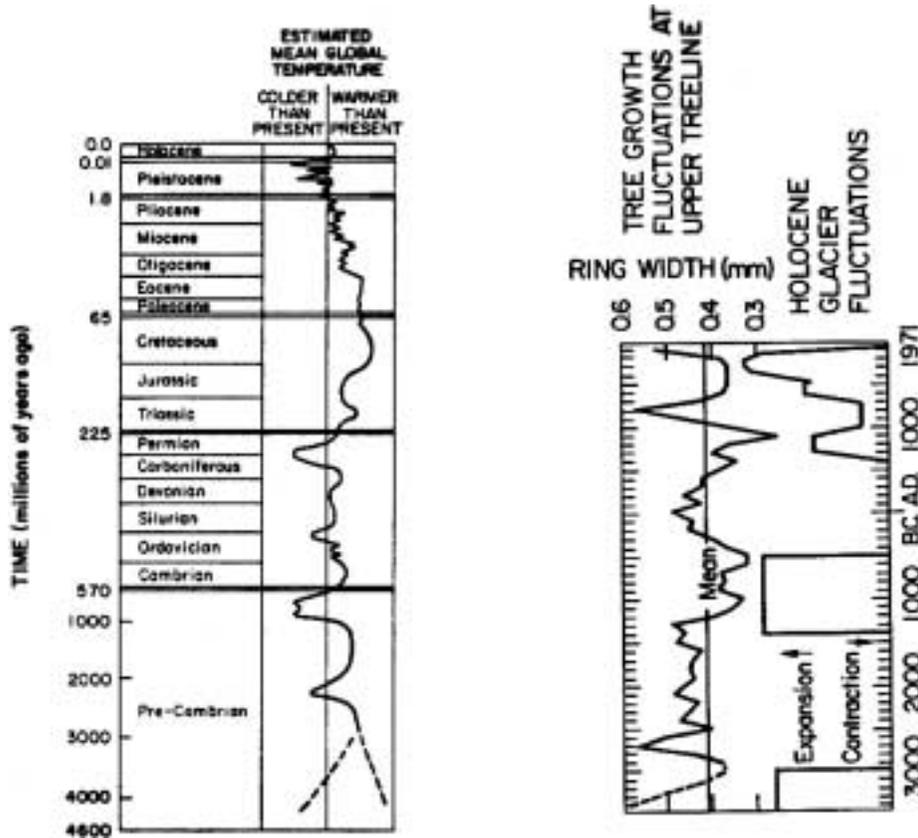


Figure 24A-2.

(A) "Variation in the oxygen isotope ratios in the shells of fossil forams [relatively large marine organisms whose shells form the bulk of chalk and common limestone deposits] living near the ocean floor taken from a deep sea core in the Pacific Ocean. If all other factors are constant, less negative values of this oxygen isotope ratio index ( $\delta^{18}$ ) indicate colder climates corresponding to increased ice volumes. ... Each major change of direction in the oxygen isotope ratio curve is called a stage, as indicated on the figure. Inasmuch as similar stages are found from deep sea cores taken all over the world, many paleoclimatologists believe that these major shifts in ... [the] index indicate a record of global climatic change over the past million years or so (copied from Schneider & Londer (1984)."

(B) "An ice core taken at Camp Century, Greenland provides a climatic record back some 120,000 years or so. When the oxygen isotope ratio index ( $\delta^{18}$ ) is large and negative, it suggests a relative absence of the isotope  $\delta^{18}$ , indicating relatively cold conditions (copied from Schneider &

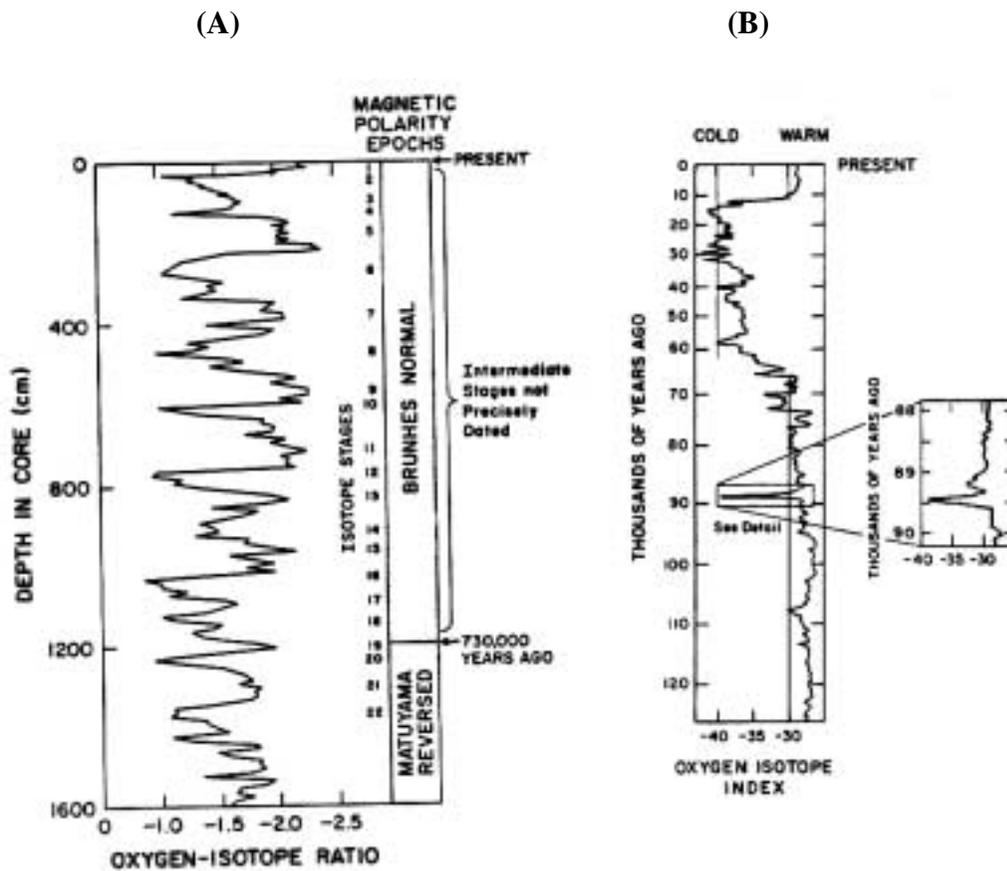


Figure 24A-3. "Analysis of a deep sea core... from the equatorial Pacific at 3°15'N 159°11'E at a water depth of 3490 m covering the last 2 million years. The geomagnetic stratigraphy indicates a time scale (shown in units of thousands of years at the bottom of the diagram) which implies that the sediment here examined was laid down over the last 2 million years.

"The upper curve registers the percentage of the sediment made up of coarse particles (>180mm cross-measurement). The coarse fraction of the sediment consists largely of the shells of foraminifera and therefore increases with the productivity of these creatures, increasing with increasing water temperature. "The lower curve plots the variations of the  $^{18}O/^{16}O$  ratio in the species *Globeriginoides sacculifera*. The variations of oxygen isotope ratio provide another indicator of the swings between glacial and interglacial regimes, the ratio increasing as the Earth goes into a glacial regime. The numbers above the lower curve identify the stages of the Quaternary climatic sequence according to Emiliani's system. (Text and figure copied from Lamb, 1977:fig 15.1)."

