Alles Introductory Biology: Illustrated Lecture Presentations

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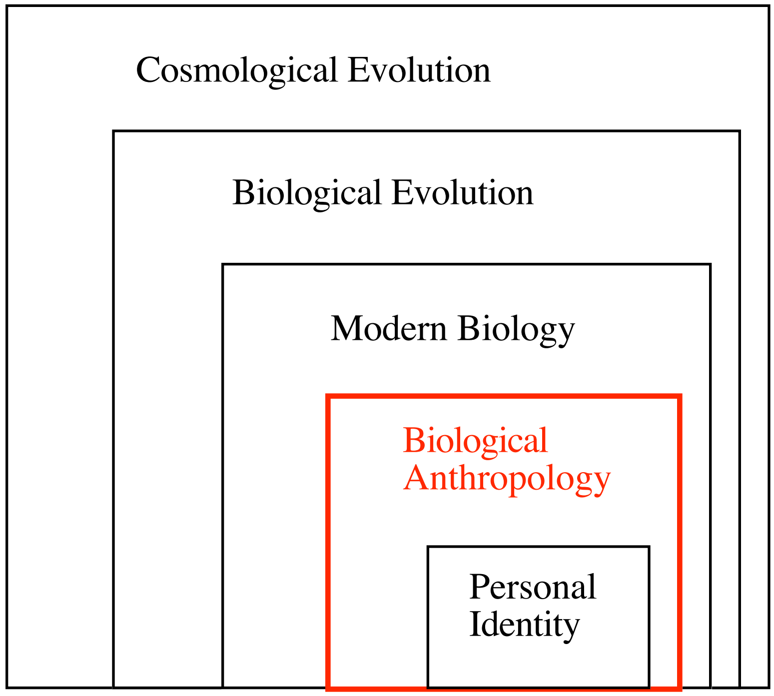
Part Three: The Integration of Biological Knowledge

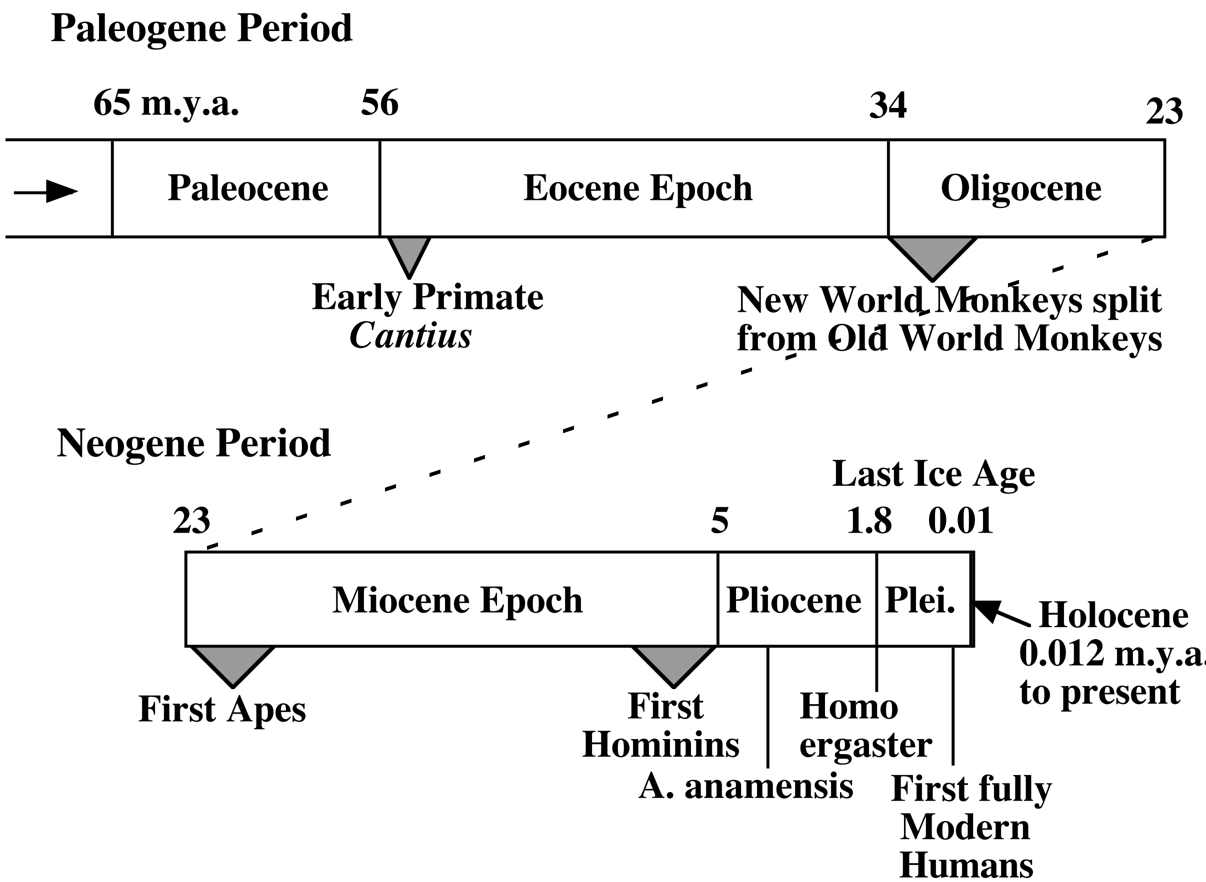
Major Events in the Cenozoic Era

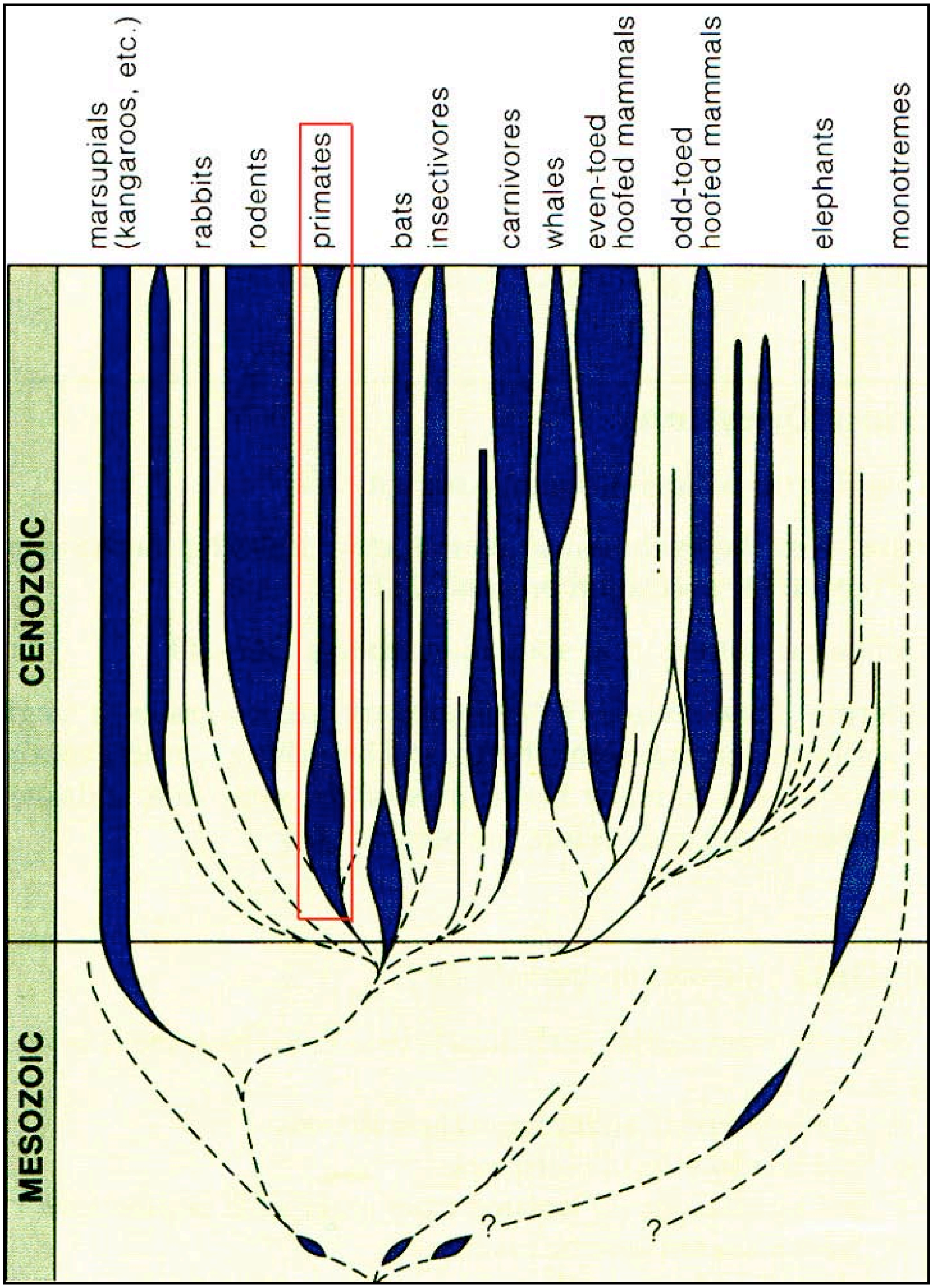
Increasingly Inclusive Concepts in Science



One of the great questions humanity must face is who and what we are. Biological anthropology, as a sub-discipline of modern biology, can now at the beginning of the twenty-first century provide scientific answers to some of these age-old questions about ourselves.

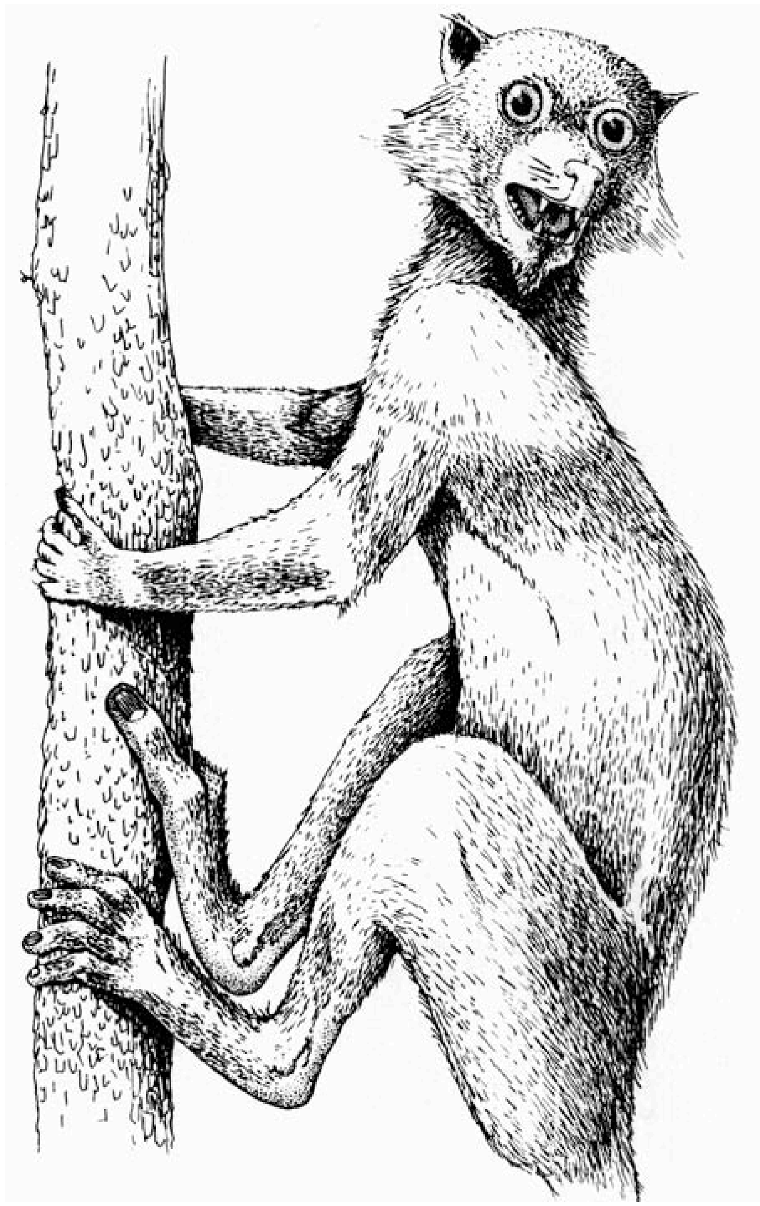
The Cenozoic Era



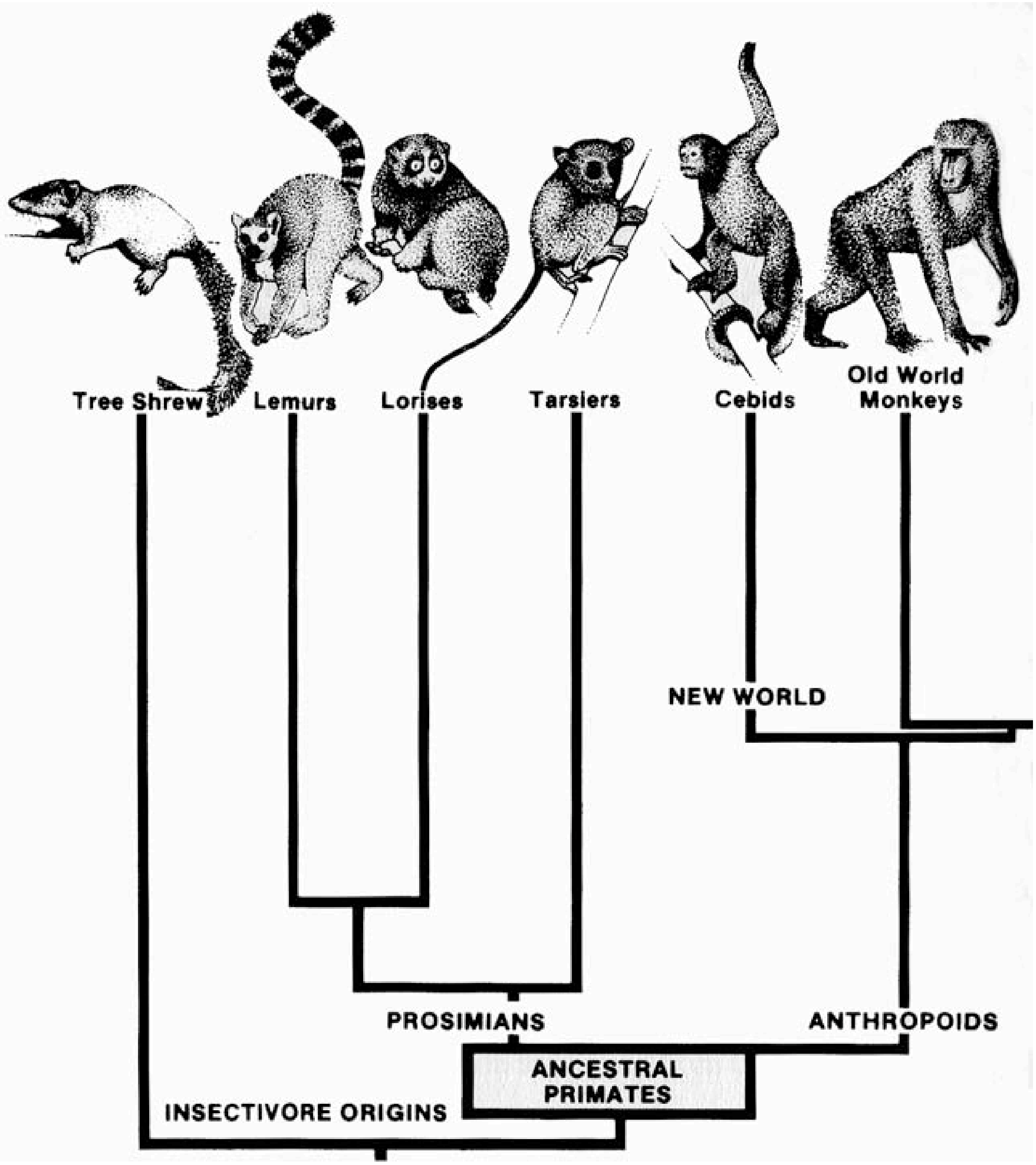


The Adaptive Radiation of Mammals

Above is a reconstruction of *Carpolestes simpsoni*, an early primate, shown foraging for fruit in the slender branches of a tree. *Carpolestes* fossils date to the late Paleocene 65 to 56 million years ago. This early primate had a grasping foot that shares several features with modern primates, including an opposable big toe with a nail rather than a claw. It could probably grasp with its hands as well (Sargis, 2002).



Cantius, known from the early Eocene ~ 54 million years ago, is one of the first true primates, more advanced than *Carpolestes simpsoni* and beginning to show some lemur-like arboreal adaptations. Note, in this drawing of *Cantius*, the flat nails and forward facing eyes characteristic of primates.



The Adaptive Radiation of Primates in the Paleogene Period

Web Reference
http://anthro.palomar.edu/primate/Default.htm

Lemurs, like this Ring-tailed Lemur from Madagascar, along with the Loirses and Tarsiers are Prosimians, primates with primitive characteristics that are believed to have descended directly from the earliest primates.

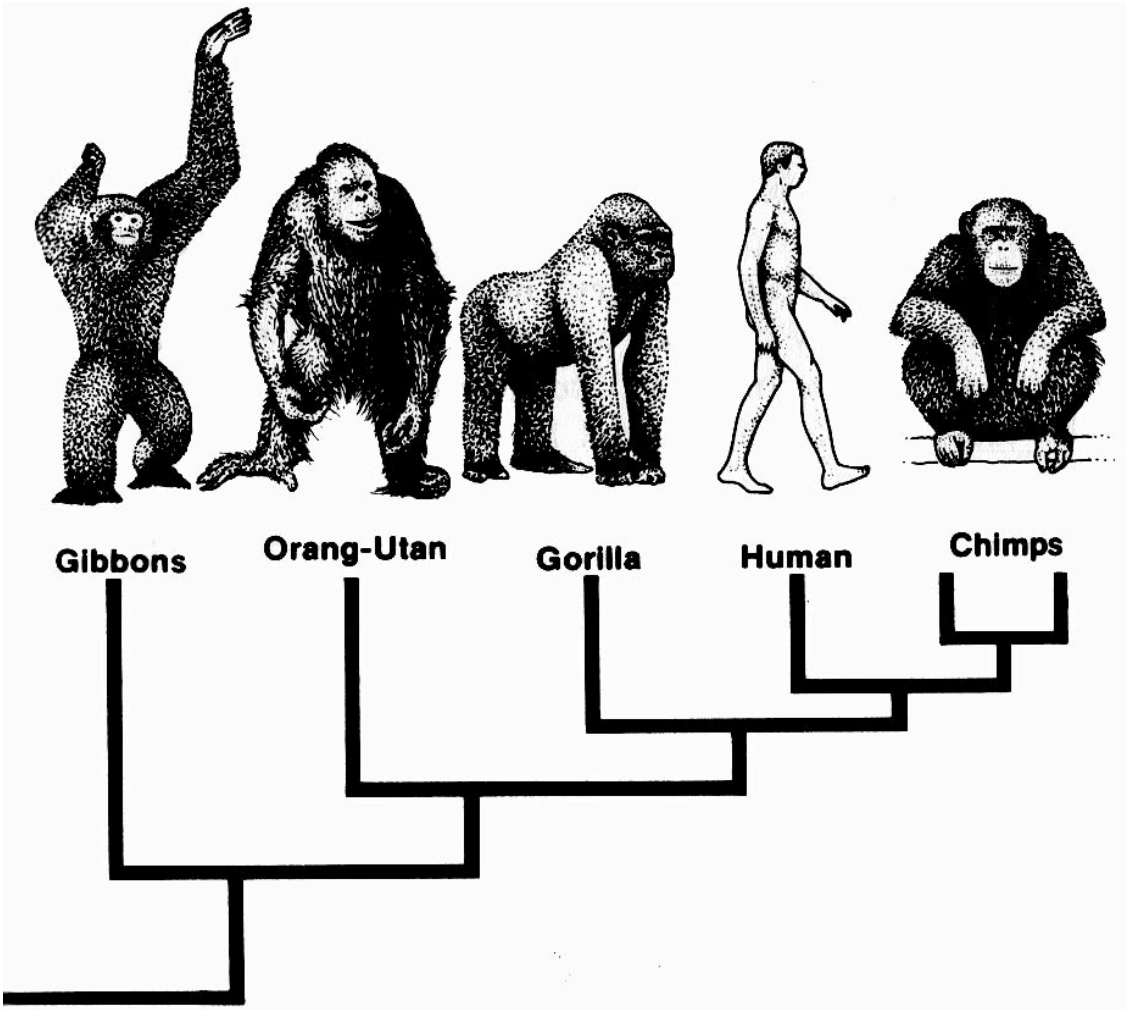
A Slender Loris from Southern India

This Tarsier from Southeast Asia has huge ears and eyes, traits it shares with the Slender Loris, both of which are adapted for foraging at night for insects.

This Golden Lion Tamarin from Brazil is a Platyrrhine or new world monkey.

Web Reference
http://anthro.palomar.edu/primate/prim_4.htm

The Gelada Baboon from the Ethiopian highlands of east Africa is a Catarrhine or old world monkey.



- The first apes evolved from Catarrhine monkeys in the early Miocene 23 million years ago in Africa.

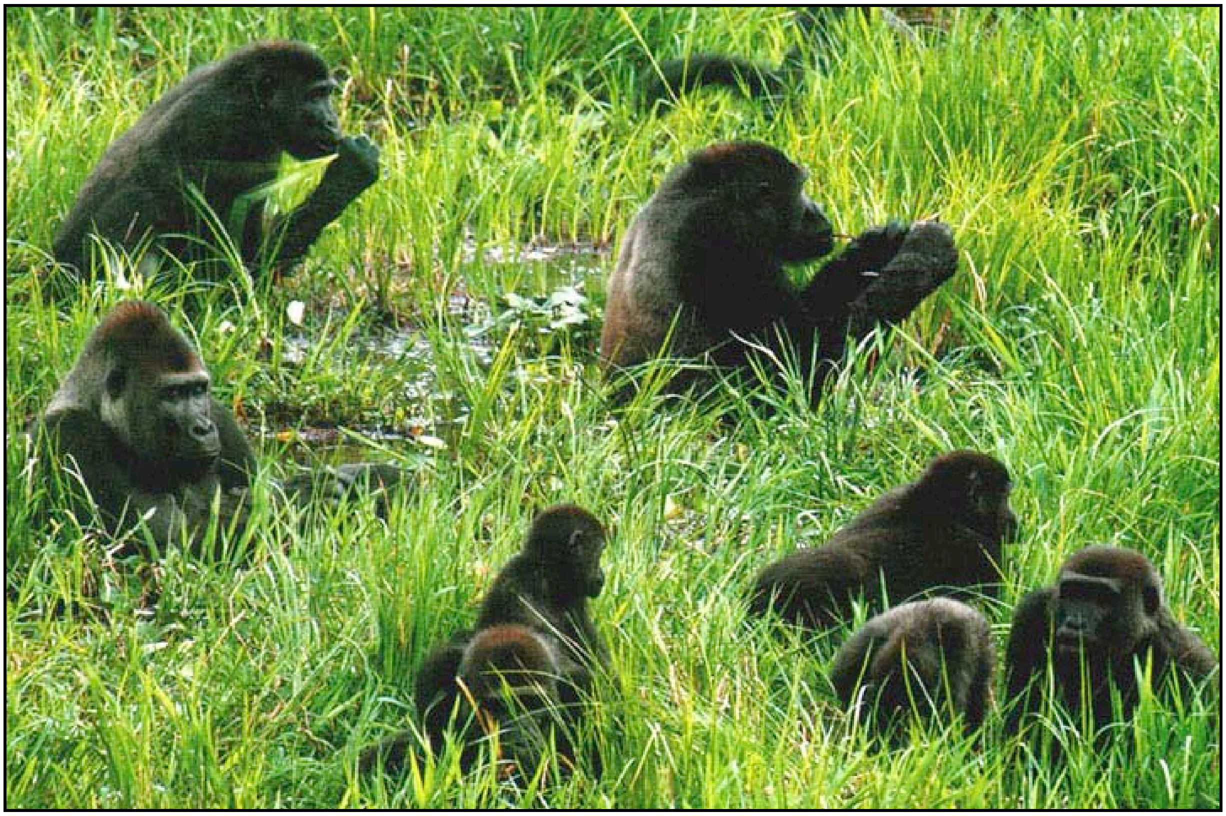
- The group then experienced an adaptive radiation of apes out of Africa to Europe and southeast Asia during the mid-Miocene approximately 12 million years ago.

- The modern descendants of the radiation in southeast Asia are the orangutan and the gibbons.

- The African apes then experienced a radiation starting 8 million years ago that gave rise to the gorillas, chimpanzees, and humans.

Web Reference
http://anthro.palomar.edu/primate/prim_7.htm#top

Above are two juvenile orangutan from southeast Asia showing brachiation, or swinging by the arms, as a means of locomotion.

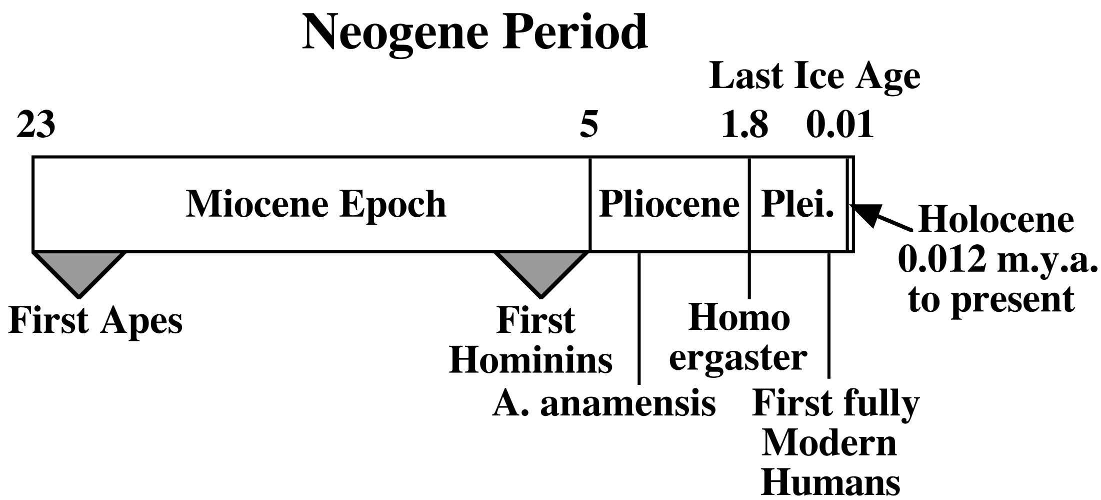


Lowland Gorillas from West Africa

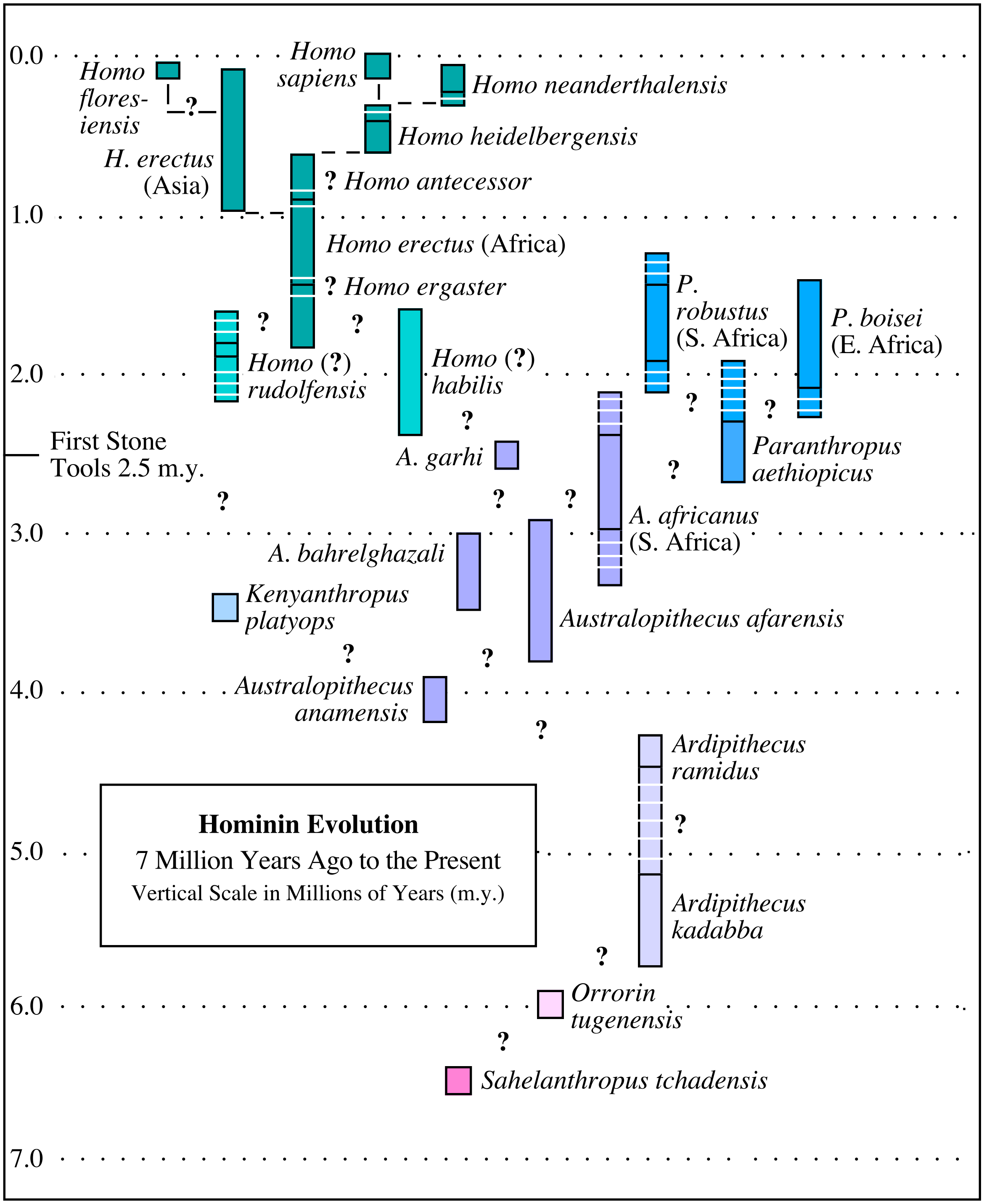
Bonobo (bo-no´-bo) Chimpanzees of West Africa

We share at least 98.5% of our genes with chimpanzees. And yet to put this in perspective relative to our treatment of the great apes, there are now more human babies born each day—about 350,000—than there are individuals left in all the great ape species combined, including gorillas, chimpanzees, bonobos, and orangutans.

Web Reference
http://www.pbs.org/wgbh/evolution/library/07/3/l_073_03.html

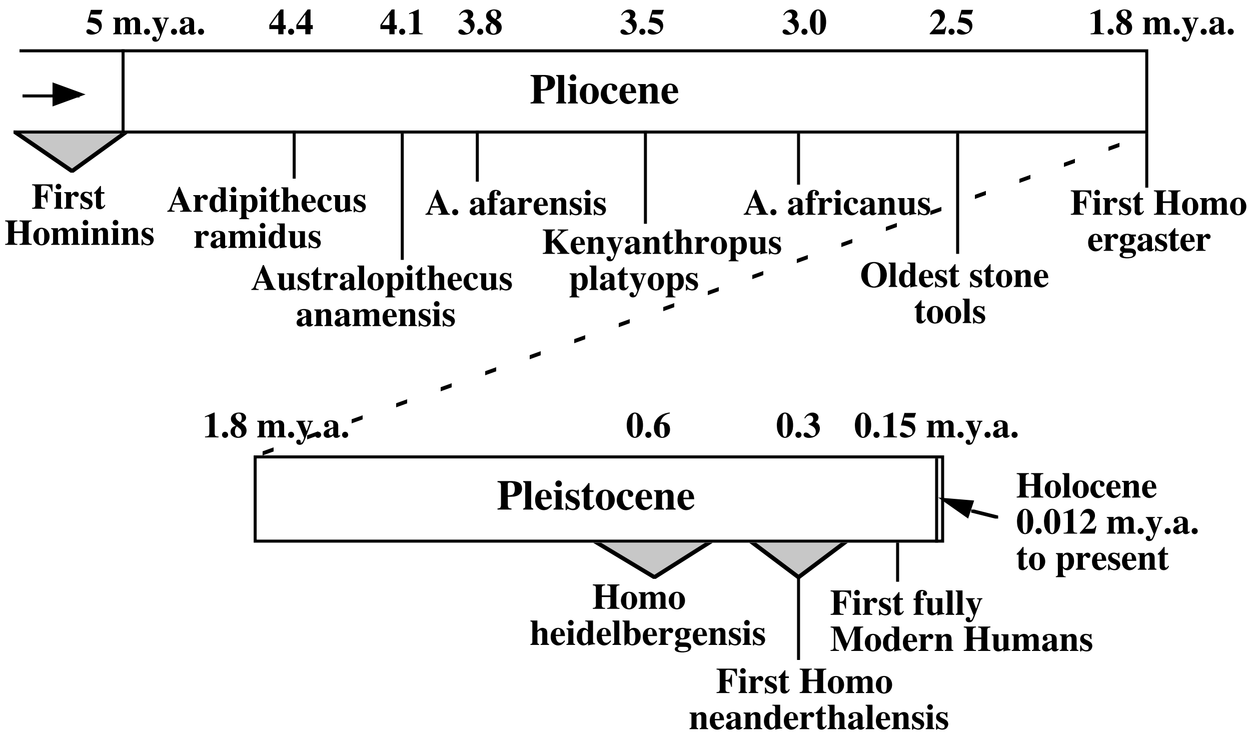


Neogene Period
Last Ice Age
23
5
1.8
0.01
Miocene Epoch
Pliocene
Plei.
Holocene
0.012 m.y.a.
to present
First Apes
First
Hominins
A. anamensis
Homo
ergaster
First fully
Modern
Humans



Rectangles represent approximate first and last dates for species.
Shading and relative horizontal position separate genera.

Pliocene to the Present



Major Trends in Hominin Evolution

1. **habitat**—from gallery forest, to open forests, to savanna

2. **locomotion**—from brachiation to knuckle walking, to first bipedal, to obligate bipedal

3. **diet changes**—tooth enamel and size—soft food, to coarse food, to soft food

4. **intestine length**—from long to short—from vegan to carnivore

5. **sexual dimorphism**—from a lot to little

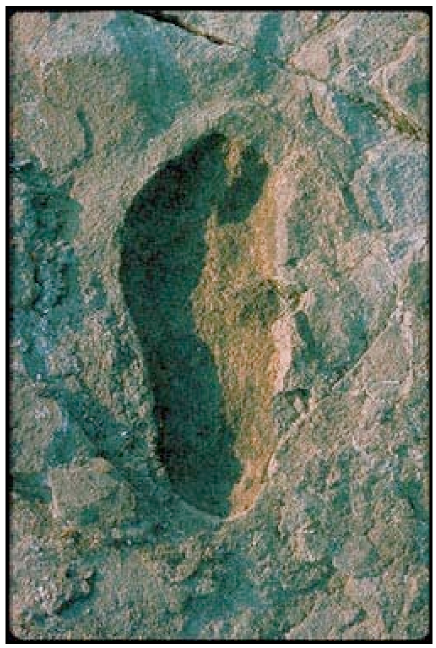
6. **cranial / body size ratio**—three spurts: *H. rudolfensis*, *H. heidelbergensis*, and *H. sapiens*

Points:

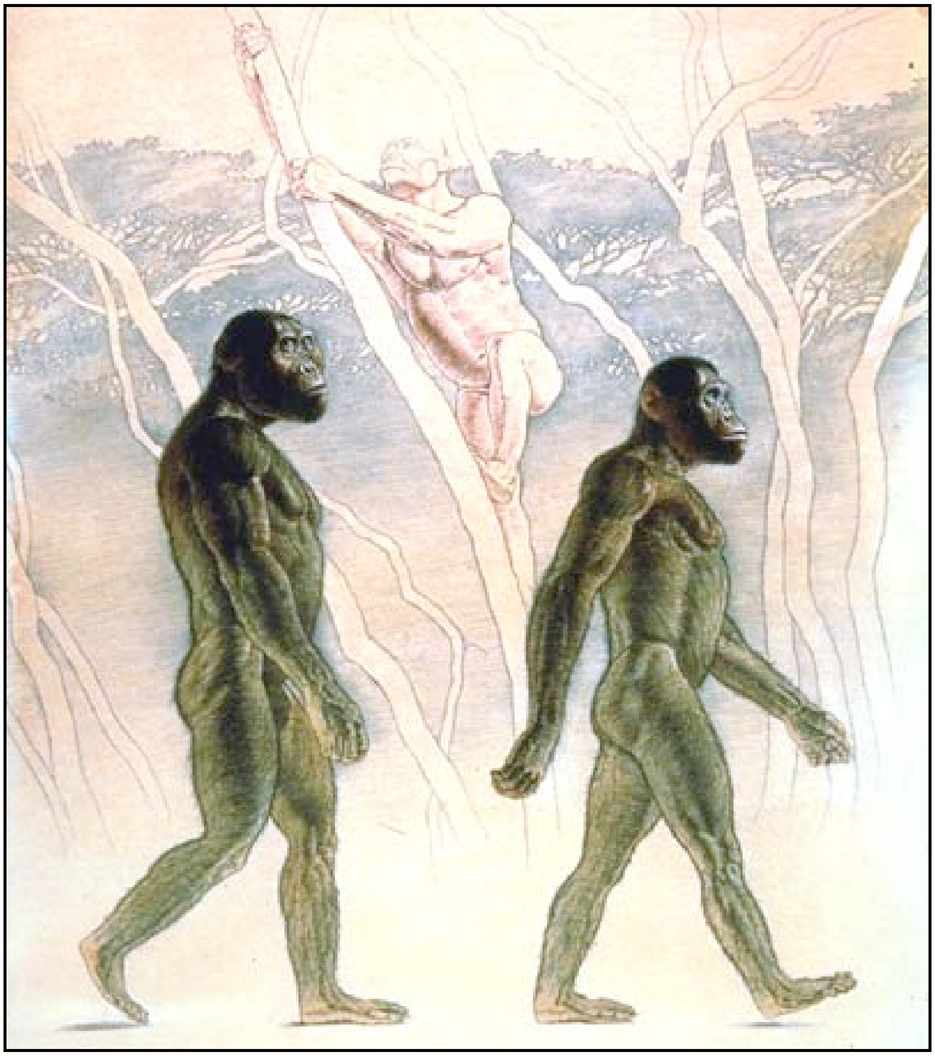
A. 7 to 5 m.y.a. last common ancestor of humans and chimps—chimps are not our ancestors.

B. Bipedalism evolved first—*Australopithecus anamensis* still had a chimp size brain.

C. *Homo ergaster* evolved a modern body but no significant increase in brain size to body size ratio.



Australopithecus afarensis, pictured above, was bipedal. This footprint from Laetoli is very human, and is dated to 3.5 m.y.a..



Australopithecus afarensis

(Painting by John Gurche http://www.gurche.com/)

Australopithecus africanus ***Homo ergaster***

For more on human evolution go to:
http://fire.biol.wwu.edu/trent/alles/Human_Evolution.pdf

On the Origin of Modern Humans

The story of human history during the last Ice Age is slowly emerging through the agency of modern science and, as is the nature of science, in a most unexpected way. The elements of the story are being put together by anthropologists, paleontologists, climatologists, archaeologists, and population geneticists. What was unexpected is that modern molecular biology has provided a growing body of evidence that answers many of the long standing questions about our origins. When did modern humans originate? Where did it happen? When did modern humans begin to spread throughout the old and new worlds? Are we related to the Neanderthals? What is the population history of human beings? How closely are we genetically related to each other? These and many other questions are now being deciphered and for the first time we can begin to piece together the history of our origin.

In the Beginning — When did modern humans originate?

"Recent research based on the full sequence of mtDNA reduced the estimate [for the origin of anatomically modern humans at about 200,000 y.a.] to slightly less than 150,000 years ago."—Cavalli-Sforza, 1998

The Garden of Eden — Where did we come from?

"Population genetic studies are in approximate agreement with archaeological observations indicating that anatomically modern humans (i.e. similar, as far as bone morphology goes, to living humans) are found in the past 100,000 years exclusively in Africa, or very close to it (the Middle East) and spread from it to the other continents."—Cavalli-Sforza, 1998

What was the size of the "founder" population of modern humans? — Rhode Island in Africa

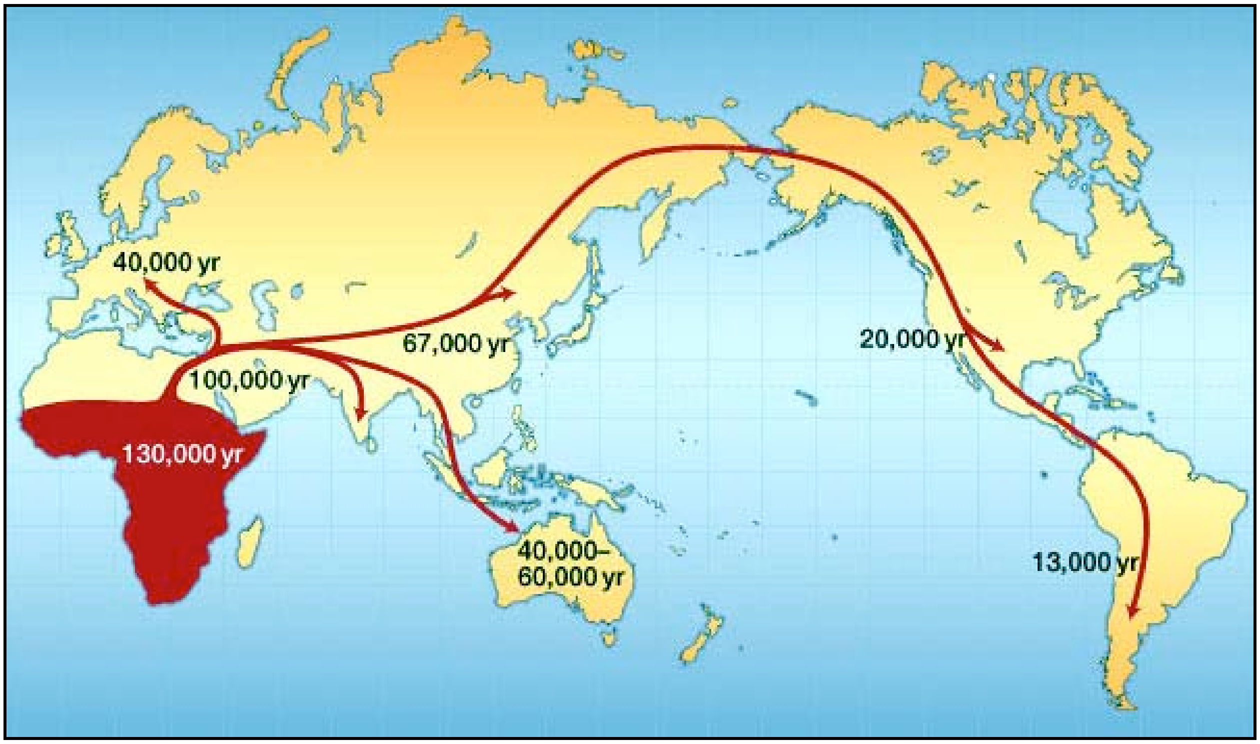
"The number of our ancestors just before the expansion ("origin") of modern humans was small. Many genetic systems provide reassuringly congruent estimates: all indicate that the approximate population size was on the order of 10,000 breeding individuals [this is 20,000 individuals total]." "Although the size of this population must have fluctuated over time, it was often reduced to the level of several thousands of adults. Such a population would have occupied an area the size of Rhode Island rather than a whole continent."—Harpending, 1998

Out of Africa

"A current estimate [for the genetic separation of Africans and non-Africans] gives a value closer to 60,000 y.a. with a standard error of close to 20% [72,000 y.a. to 48,000 y.a.]."—Cavalli-Sforza, 1998

Why did modern humans spread out of Africa? — The Walker Predator Density Hypothesis

If you invent a new way of hunting, be it cooperation, new and better weapons, modern language, or any combination of these, then you are faced with the predator density problem (Walker & Shipman, 1996). That is, as you become a more efficient predator, you run the risk of killing off your prey species. The only long term solution for hominids, in this case, is to reduce population density per unit area. This puts tremendous pressure on populations to disperse in search of new prey. In other words, increased hunting efficiency leads to a form of competitive release by enforced range expansion. The spread of modern humans out of Africa (and Homo erectus before them) resulted from competitive release brought about by qualitative increases in hunting efficiency. But several factors had to be available. You had to have someplace to spread to, for example. Modern humans originating in Africa, as they did, had all of Eurasia to spread into reaching Australia between 60,000 and 53,000 y.a. and Europe by 40,000 y.a., and eventually, by way of the Bering land bridge, all of the Americas.



The Origin and Dispersal of Modern Humans

The time of origin of modern humans is not well known but may have been about 150,000 years ago based on genetic evidence. New evidence from mitochondrial genomes bolsters the hypothesis that the place of origin was sub-Saharan Africa and that the dispersal from Africa occurred within the past 100,000 years. The earliest known fossil and archaeological evidence on each continent, shown on the map, is consistent with this view (Hedges, 2000).

Relatives? — the Neanderthals

A dramatic study done in 1998, where traces of mitochondrial DNA were extracted from the first Neanderthal fossils ever found, has provided compelling genetic evidence that we are not closely related to the Neanderthals. "More than 380 nucleotides in region 1 of the D-loop [of mtDNA] were studied. The average difference among pairs of modern humans is 8.0, while the range of the difference between a modern human and Neanderthal is 22-36. These results put Neanderthal out of the modern human line, and confirm that it is most probably completely extinct." (Cavalli-Sforza, 1998) In March of 2000, a second report of Neanderthal mtDNA being extracted was published in the journal *Nature* (Hoss, 2000). This second mtDNA analysis was from a Neanderthal found in the northern Caucasus dated to 29,000 years ago. "...it provides invaluable corroboration for the authenticity of Neanderthal mtDNA sequences."(Hoss, 2000) These DNA studies are supported by fossil and archaeological evidence in showing that by 29,000 y.a., approximately ten thousand years after modern humans had arrived in Europe, the Neanderthals were extinct. Thus the Neanderthal found in the northern Caucasus may be one of the last members of this sister species to modern humans.

What is the demographic history of the prehistoric human population?

Two major periods of exponential expansion in the population of early modern humans can be identified. The first resulted from modern humans spreading out from their homeland in Africa. The second is the result of the invention of agriculture.

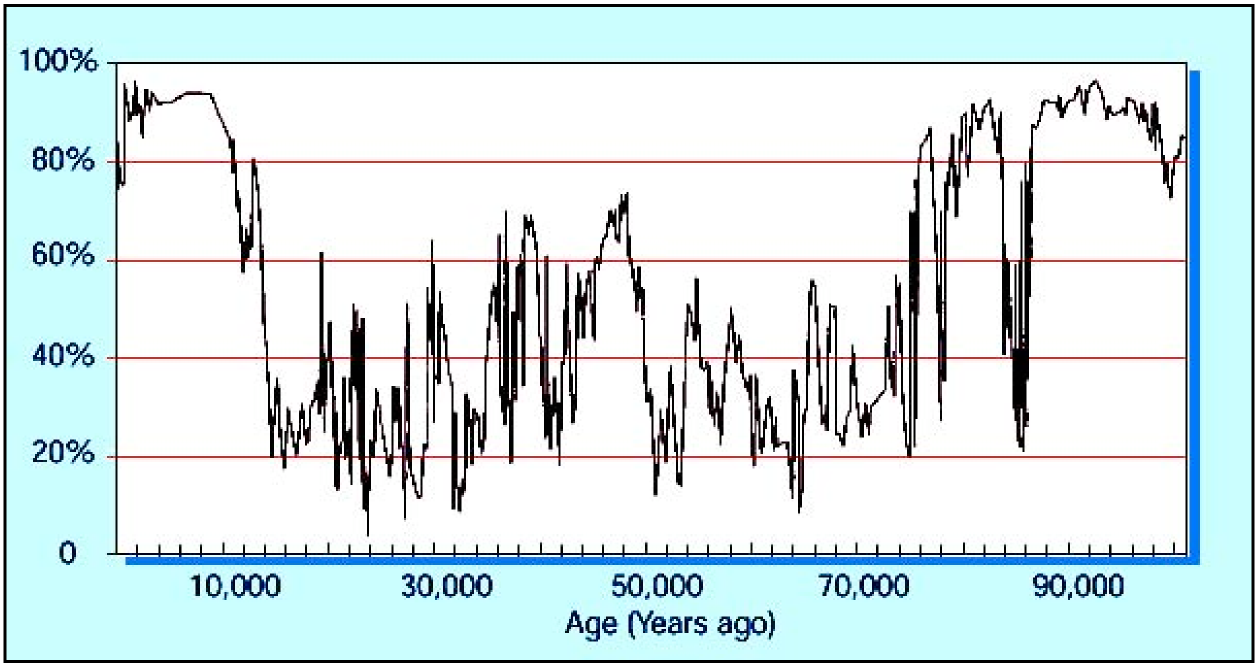
During the Middle Paleolithic (200,000 to 44,000 y.a.) "early human populations were exceptionally small, even by later Paleolithic standards and [it appears] that early Middle Paleolithic humans did not spend much time foraging in any one vicinity." (Stiner, 1999) At some point, however, early modern humans in Africa developed new hunting technologies which lead to their expansion out of Africa ~ 60,000 years ago. This expansion into virgin territories, together with new hunting technology, caused the first period of exponential growth in human numbers. The human population did grow exponentially during this period, however densities were kept low by the combination of reliance on hunting and the violent climate swings of the Late Pleistocene (see below).

The second major pulse in human population growth is associated with the invention of agriculture. But if you have been successful as hunters and gathers for thousands of years, why invent agriculture? The answer lies in the combination of three events.

First, the climate changed 11,500 y.a.. Why didn't humans invent agriculture a hundred thousand years ago? The first modern humans were identical to us and, therefore, surely intelligent enough to do so. Why did the invention of agriculture and the population explosion that followed have to wait until 12,000 to 10,000 years ago? Part of the answer is in the weather.

All during the Pleistocene Ice Age violent weather was the norm, and not until the interglacial climate shift 11,500 years ago did the violent swings in climate settle down to our present calm state. Peter Ward provides this picture:

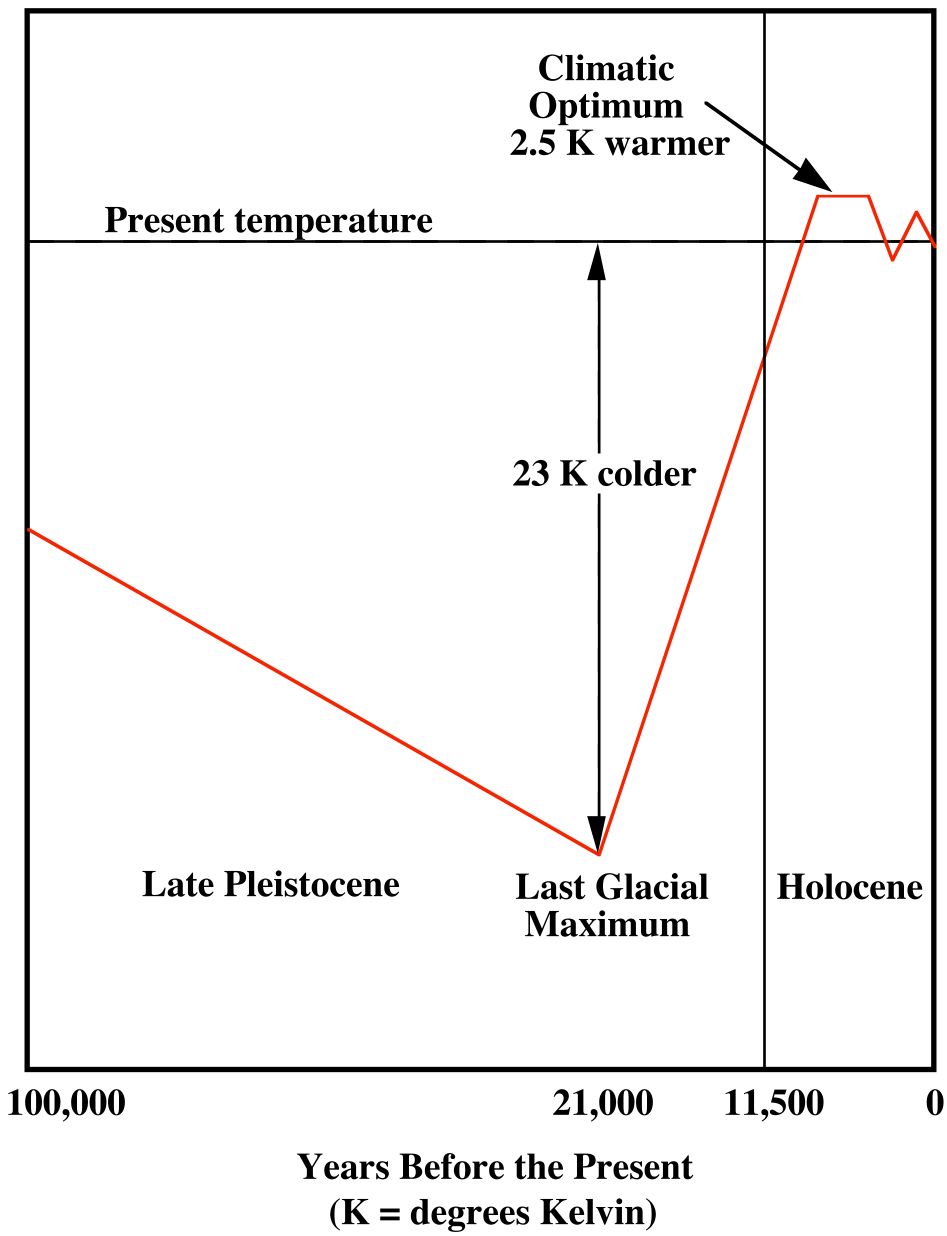
"The analysis of oxygen isotopes from the Greenland ice cores have shown that the climate over the past 250,000 years has changed frequently and abruptly; the magnitude of the global temperature changes has been far greater, and their intervals far shorter, than anyone imagined. Dr. J. White of the University of Colorado, noted in a recent summary that between 200,000 and 10,000 y.a., average global temperature had changed as much as 18° F in a few decades. The current average global temperature is 59° F. Imagine that it suddenly shot up to 75° F or sank to 40° F in a century or less. At a minimum, these sudden changes would create catastrophic storms of unbelievable magnitude and fury. Yet such changes were common until 10,000 years ago. Imagine a world where storms that dwarf Hurricane Andrew lash the continents not once a century but several time each year, every year. Imagine a world where tropical belts are suddenly assaulted by snow each year. This was our world until 10,000 years ago, when, according to the studies of the Greenland ice cores, a miracle happened: The sudden shifts in the weather stopped."—Ward, 1997



From the end of the last interglacial period ~ 100,000 years ago until ~ 12,000 years ago the Earth’s climate has experienced severe and abrupt changes.

Web Reference
http://www.esd.ornl.gov/projects/qen/nerc130k.html

Changes in the Average Annual Temperature from the Late Pleistocene to the Present



(Data is averaged to show major trends.)

Second, modern humans in area after area reached their density limit as hunters. By the Upper Paleolithic (44,000 to 19,000 y.a.) hunting pressure had forced people's attention from slow moving prey to fleeter prey types. This is, after all, what happens when you spread out and then kill off your preferred (which usually means easier to catch) prey species. Once your population spreads out and fills all available habitats, however, you can't do it again (this is the notion of demographic packing). So if your population increases, it must increase your density per unit area, thereby putting even greater pressure on food resources. "Mobility was the preferred solution to local resource scarcity throughout much of prehistory. Any loss of mobility options is a grave matter for people who live by hunting and gathering. The changes in prey species during the Mediterranean Paleolithic nonetheless indicate demographic packing and associated reductions in mobility."
—Stiner, 1999

And third, by 11,000 y.a. modern humans had killed off the Pleistocene megafaunas, the mammoths, mastodons and ground sloths along with many other large species, of both the old and new worlds. In North America 73% of all genera weighing more than 100 pounds went extinct between 12,500 to 11,000 y.a., not long after humans arrived on the continent (Ward, 1997; Flannery, 1999). "But Australia suffered the most severely of all the continents, losing every terrestrial vertebrate species larger than a human," (Flannery, 1999). Most telling of all is that the Australian extinctions again coincided with the arrival of humans, only this time at around 50,000 years ago, at least 30,000 years before humans reached the Americas.

On the one hand the extinction of the Pleistocene megafauna put selective pressure on early human hunters to find other food sources, at the very least smaller game, whereas the climate change allowed that new food source to be cultivated plants. An example in support of this hypothesis comes from Pringle:

"In a layer dated to at least 13,000 y.a. the [rice] phytoliths show that hunter-gathers in the cave were dining on wild rice. But by 12,000 y.a., those meals abruptly ceased—Zhao suspects because the climate became colder and the wild grain, too tender for such conditions, vanished from this region. Studies of the Greenland ice cores have revealed a global cold spell called the Younger Dryas from about 13,000 to 11,500 y.a.. As the big chill waned, however, rice returned to the region. And people began dabbling in something new around 11,000 y.a.—sowing, harvesting, and selectively breeding rice."—Pringle, 1998

The invention of agriculture caused the second period of exponential growth in the human population by allowing increases in population density per unit area rather than range expansion. Note that new studies of the origin of agriculture clearly place the origin at the interglacial climate shift 11,500 years ago.

Two Possible Histories of our Origin

A summary of the preceding essay might read as follows.

Sometime around 150,000 years ago, somewhere on the continent of Africa, the morphology of an isolated population of approximately 20,000 early humans became indistinguishable from that of humans today. This population over time developed more efficient hunting techniques that produces two outcomes. The population increased but was also forced to expand its range. As time passed this combination lead to modern humans spreading out from Africa, first to Eurasia, then to Australia (~ 50,000 y.a.) and on to Europe (~ 40,000 y.a.), and finally to the new world (20,000 to 14,000 y.a.). Once the world was covered with modern humans the pressure of their hunting caused the extinction of the Ice Age monsters, the mammoths, woolly rhinos, giant ground sloths and many other almost mythological creatures. And along with the Ice Age megafauna our nearest relative the Neanderthals also went extinct. Still the pressure of increasing population did not end. Instead new sources of food would be found, this time from the earth itself. But fate also had to intercede. The violent climate of the Ice Age ended as if on cue.

All of these forces, demographic packing, the extinction of big game, the end of violent climate swings, and increasing population pressure, may have combined to lead to the invention of agriculture in the old world between 12,000 and 10,000 years ago. But with that invention the world changed forever as the human population began, slowly at first, its incredible explosion in numbers. Today, it is increasingly clear that we are near the end of that explosion. Although we still do not know what will bring it to a halt, what does seem certain is that the outcome will be known within the lifetime of children born today.

Excerpt from **What We all Spoke When the World Was Young**

by Nicholas Wade

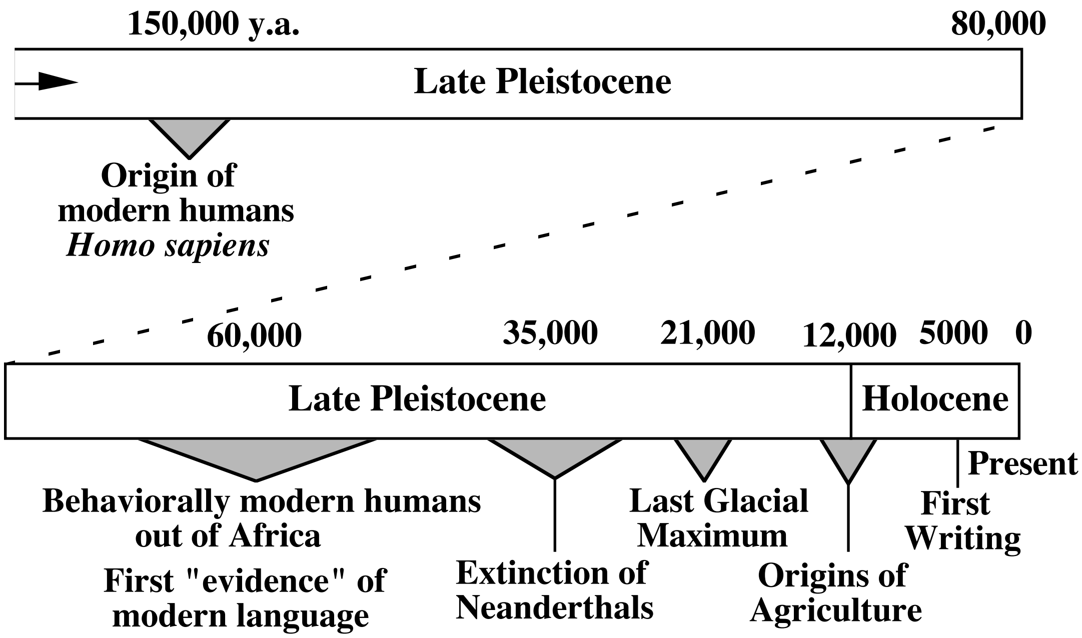
"In the beginning, there was one people, perhaps no more than 2,000 strong, who had acquired an amazing gift, the faculty for complex language. Favored by the blessings of speech, their numbers grew, and from their cradle in the northeast of Africa, they spread far and wide throughout the continent.

One small band, expert in the making of boats, sailed to Asia, where some of their descendants turned westward, ousting the Neanderthal people of Europe and others east toward Siberia and the Americas.

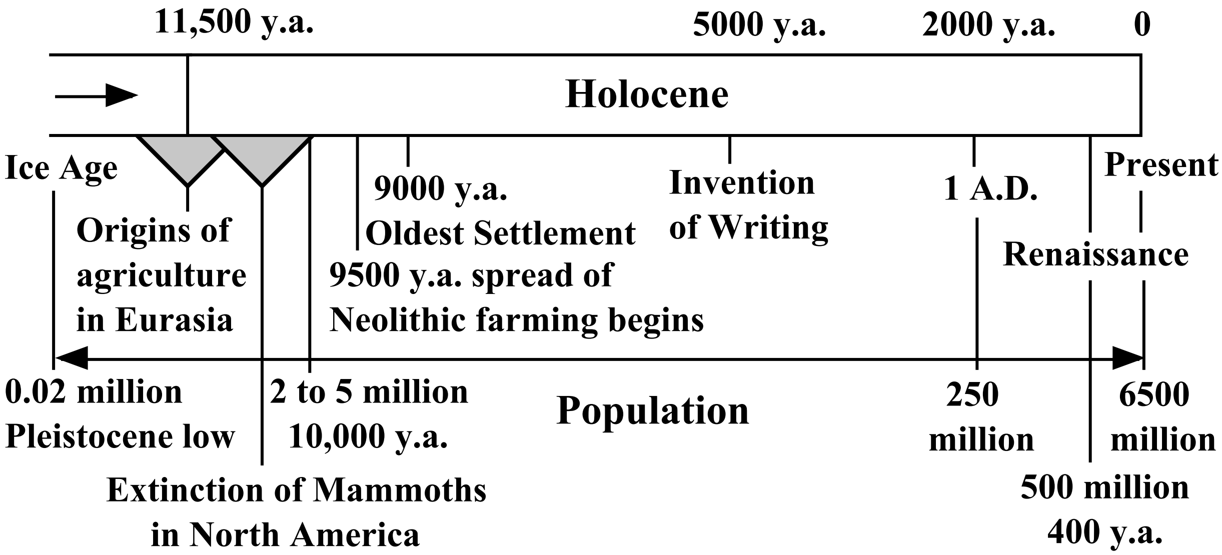
These epic explorations began some 60,000 years ago and by the time the whole world was occupied, the one people had become many. Differing in creed, culture and even appearance, because their hair and skin had adapted to the world's many climates in which they now lived, they no longer recognized one another as the children of one family. Speaking 5,000 languages, they had long forgotten the ancient mother tongue that had both united and yet dispersed this little band of cousins to the four corners of the earth.

So might read one possible account of human origins as implied by the new evidence from population genetics and archaeology."—Wade, 2000

Late Pleistocene to the Present



The Holocene Epoch



Human Evolution

"Our human bodies record a sequence billion of years longer than human culture. Nested like Russian dolls are features that we share with more and more organisms the deeper we probe. As humans, we have uniquely large brains and upright posture; as primates, fingernails and stereoscopic vision; as mammals, hair, warm blood and milk-fed young; as amniotes (the group that includes mammals, birds, and reptiles) internal fertilization and the ability to reproduce ourselves outside a watery environment. With other vertebrates we share a rigid internal skeleton. All animals have tissues, and all of us collect our carbon and energy from organic compounds derived from all those plants, algae, and bacteria that can use either chemical energy or light to manufacture their own supplies out of non-living raw materials. Like almost all organisms except bacteria, we have cells with nuclei and chromosomes, organelles, and an oxygen drive. In common with every living thing we have DNA, genetic blueprints, and metabolism—the equipment to absorb, dismantle, and exploit useful molecules.

This sequence is a journey proceeding out of time. Listed so simply, it is apt to sound like the flow of a single force with an inevitable outcome. Yet the long-range order that we see with hindsight is the outcome of a blizzard of causes blowing this way and that. It shows that evolution has not worked like a single steamroller headed in some purposeful direction, but as a set of improvisations and haphazard events, constantly reinventing itself. Rather than redesigning the fundamental machinery of life, evolution appears to have tinkered with the most variable and possibly least essential details. When such changes happen at the right time and place, they may prove useful as conditions change. Like our fellow species, we are a ramshackle collection of these useful adaptations, with layer tacked on to underlying layer, each one reflecting the successful inventions of bygone times."

J. John Sepkoski Jr. in Gould (ed.) (1993)

To Make a Human Being

4000 m.y.a. the evolution of the cell, DNA, and cellular metabolism

2000 m.y.a. the evolution of aerobic respiration and eukaryotic cells

1100 m.y.a. the evolution of sexual reproduction

700 m.y.a. the evolution of multicellular animals

520 m.y.a. the evolution of the notochord

360 m.y.a. the evolution of terrestrial tetrapods

300 m.y.a. the evolution of internal fertilization and the amniotic egg

180 m.y.a. the evolution of hair, warm-blood, and milk to suckle young

55 m.y.a. the evolution of fingernails and stereoscopic vision

4.1 m.y.a. the evolution of walking upright—bipedalism

2.5 m.y.a. the evolution of stone tool making

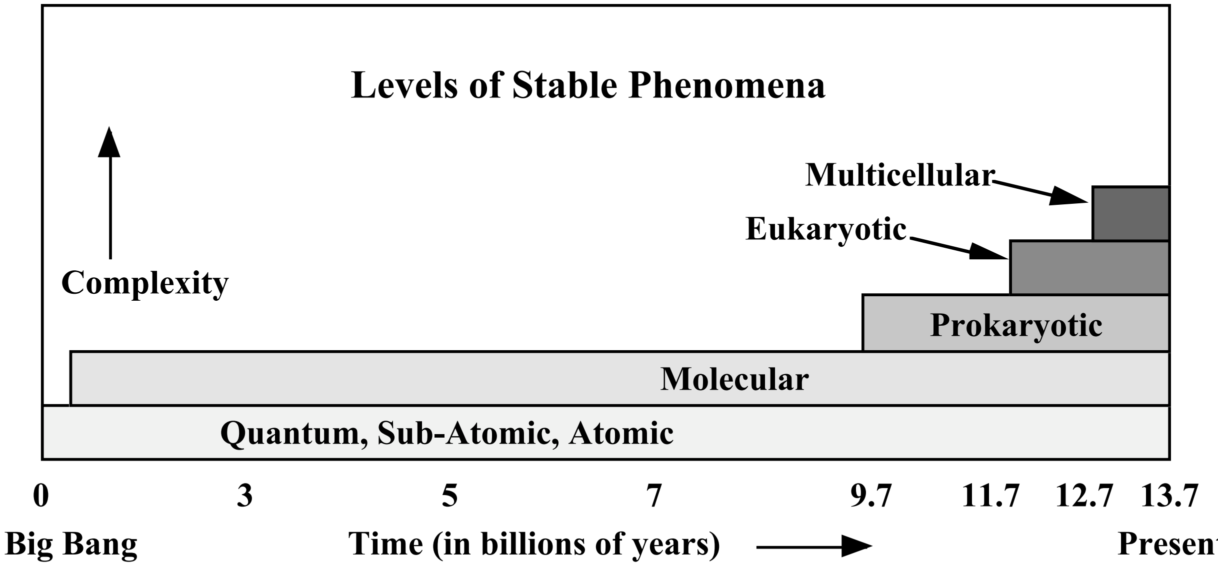
1.8 m.y.a. the evolution of the genus *Homo*

0.15 m.y.a. the evolution of anatomically fully modern humans

0.06 to 0.04 m.y.a. the evolution of modern language

0.005 m.y.a. the invention of writing

How can we organize our knowledge of the natural world?



1. There is a chronological sequence in which the universe developed.
2. Levels of stable types of phenomena are built upon other more basic levels.
3. These levels of stable phenomena have accumulated through time.
4. Life on Earth is one of these natural levels of stable phenomena.
5. Evolution can explain the development of all these levels of stability.

Science

What is it?

And what does it say about our world?

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