CHAPTER 10^7: THE LAST FEW TEN-MILLION YEARS (30 MILLION – 3 MILLION YEARS AGO)

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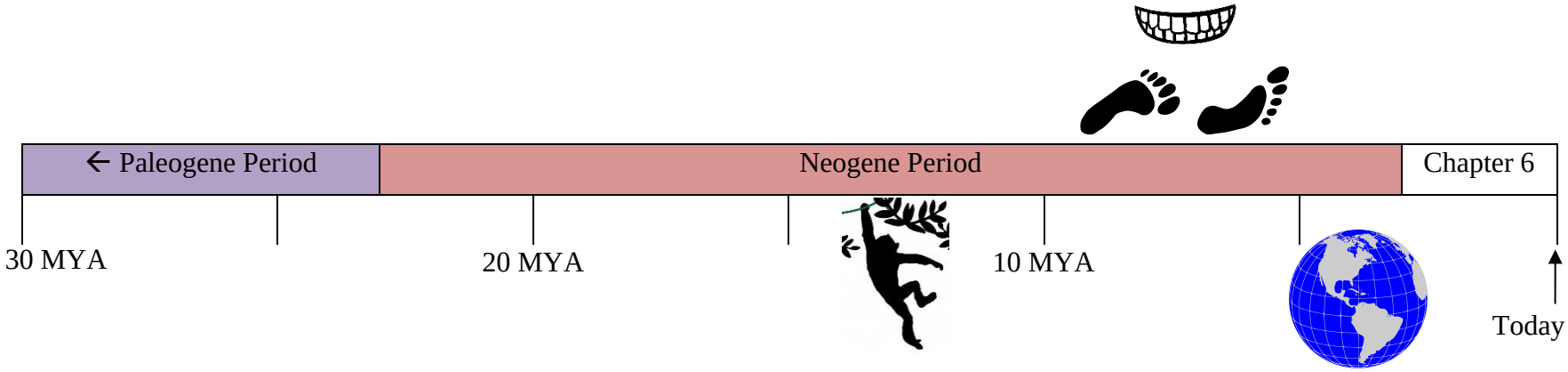
I. Introduction

Chapter 7, the ten-million year timescale, is probably one of the least familiar to the collective consciousness. It is underrepresented in school curricula and popular culture. Maybe this is because its icons, fossil apes, are less charismatic than dinosaurs or cavemen. Moreover, fossil apes are more recent discoveries. We will see, however, that Chapter 7 includes some significant developments. This was the time when our phylogeny narrowed down to our very own clade, the proto-humans (***hominins***), with genes that are now uniquely human. This last point is a contentious issue for many religious parents, and grade-school teachers tend to gloss over this phase of natural history due to the sensitivity of the topic as well. [1]

As shown on the timeline below, Chapter 7 coincides mostly with what geologists call the ***Neogene*** Period (23 to 3 MYA). Section II opens the chapter with a description of the Neogene environment. The geography of the last 30 million years took the Earth's climate in a whole new direction.

Section III outlines the evolution of the fossil apes, from early primates to hominins. Section IV further defines the hominin in terms of the fossil record. Fossils tell us directly about the evolution of our body's hard parts. There is more to a skeleton than meets the eye. Bones and teeth provide ample clues about diet, habitat, motion, and even behavior.

We can learn even more by observing our most closely related species, the great apes. Living species have soft tissue – muscles, brains, and hair – to compare to our own. Ape behavior and social structure can also give us insight into the long-term evolution of human nature. This comparative analysis is the subject of Section V.



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II. The Neogene Period: A Newborn World

A. The Seven Continents and the Seven Seas

Evolution is guided by the environment. To put our ancestors' evolution in context, then, we should understand the changes taking place in their world.

By the end of Chapter 8, the continents had reached *roughly* their present-day configuration. There were a few key differences. 20 – 40 million years ago, Africa slowly coalesced with Eurasia, forming a permanent juncture at the Arabian Peninsula. [3] Depending on land and sea levels, which fluctuated drastically, there was sometimes a land bridge at the Strait of Gibraltar. Even the Mediterranean Sea dried out at least twice. [4] Fluctuating sea levels also caused intermittent contact between North America and Europe and / or Siberia.

South America was isolated for tens of millions of years. It separated from Antarctica late in the Paleogene Period. Since that time, a cold circumpolar current has flowed from west to east around the Antarctic. There was once a warm parallel current between North and South America. South America's northward drift closed that gap. The Isthmus of Panama was formed gradually by the forces of plate collision; it was not a lucky strike between two narrow necks of land. [5] By three million years ago, the land bridge was complete. [6] That tiny isthmus had huge ecological and climatic effects. It joined the terrestrial life of two continents while cleaving marine life into two oceans. It redirected the warm tropical waters of the Caribbean Sea northward along the coastline of North America. This ***Gulf Stream*** brought warmer, moister air to northern Europe, making that region unusually warm for its latitude (consider that London, England is at the same latitude as Calgary, Canada). The Gulf Stream water and air is carried all the way to the North Pole, where the humidity precipitates and contributes to the northern ice cap.

Asia was the least-developed continent 30 million years ago. At that time, the southern continent comprised numerous island arcs resembling today's Indonesia and Philippines. The processes of plate tectonics, orogeny, erosion and sedimentation gradually filled it out. The Indian / Asian collision intensified around 25 million years ago, when the oceanic crust was completely subducted and the continents themselves butted up against each other. [7] Since then, India has been slipping beneath Asia, causing a massive uprising of land. The rugged Himalayan Mountains are

the highest in the world. Just to their north is the Tibetan Plateau, also the world's highest. The Himalayan-Tibetan region is now the site of large glaciers and the source of major rivers. The high wall of land intensifies South Asia's annual monsoons. Summer clouds from the Indian Ocean dump all their moisture on the southern face of the Himalayas. The mountains leave a "rain shadow" to the north, making much of central Asia a vast desert.

Earth entered a significant cooldown period 15 million years ago. Carbon dioxide levels fell, [8] perhaps contributed by weathering of carbon-absorbing rock in the Himalayas. [9] The north and south poles both acquired their permanent ice caps during the Neogene, aided by the moist Gulf Stream to the north and the cold polar current to the south. By reflecting the sun's heat, ice caps themselves contributed to further cooling. A cooler Earth is a more seasonal Earth, more prone to snow and ice each winter.

B. Modern Ecosystems

You probably remember studying the "food chain" in grade school: carnivores eat herbivores, which eat plants and fungi. Plant life is the foundation of the ecosystem. Plants, in turn, adapt to the climate and the geography of their environments. Thus, as the physical world – the continents, oceans, and atmosphere – made significant changes over the last 30 million years, plant life also changed and animals followed suit. The name *Neogene* means *newborn*. This period was so named because of the new ecosystems that followed the climatic changes.

The general trend over the last few ten-million years has been a cooler, drier Earth with a more diverse range of ecosystems. Plate tectonics produced major new mountain ranges on virtually every continent – the Rockies, the Andes, the Alps and Himalayas – which cast rain shadows to the inland side. The mountains themselves provided a greater range of high-altitude habitats. As the Earth cooled overall, jungles receded closer to the equator, thus becoming truly the "tropical" forests as we know them today. [*] This had great bearing on our ancestors, who occupied the dense forests of the Paleogene and Neogene.

In temperate latitudes, rain forests were replaced by woodlands and grasslands. In everyday speech, we use terms like "forest" and "woodlands" loosely and interchangeably. To an

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[*] "Tropical" by definition means "Within 23.5º latitude of the equator," the part of the world that gets perfectly vertical sunlight at some time of the year.

ecologist, a forest is what we would call a jungle, a densely populated range of evergreen trees. There is an overarching canopy of broad leaves over most of the forest, with shorter trees underneath. Forests are humid, shady, and rich in fruit and invertebrates. ***Woodlands*** are less dense and have only one layer of trees, which often lose leaves in the fall. A woodland floor is sunnier than a forest and more likely to support bushes and grass.

In plains with insufficient rainfall to support many trees, grasses dominate the landscape, punctuated by occasional groves of trees or bushes. The Neogene Period is characterized by the spread of grasslands and ***savannas***, the boundaries between woodlands and grasslands. Grasslands helped accelerate global cooling by absorbing more greenhouse gases and emitting less water vapor than forests. [10]

As the density of trees decreases, so does the density and diversity of animal life. Woods and grasslands offer a much less luscious menu than forests. The herbivores that thrive in grasslands have adapted to eating nutrient-poor grasses, seeds, and even bark. The Paleogene and Neogene periods saw a radiation of grazing hoofed mammals such as camels, horses, and hippos. [11] Hoofed animals were highly successful. They largely displaced more primitive mammals such as marsupials. The main exception was Australia, the most isolated continent. Hoofed animals were unable to reach Australia, so marsupials like kangaroos and wombats remained the dominant mammals. [12] Elephants and sloths are other large herbivores that first appeared in late Paleogene grasslands.

As for carnivores, the Paleogene Period saw the rise of dogs, cats, and bears. [13] An older form of carnivores, the now-extinct *creodonts*, also survived into the Neogene. The grasslands environment produced a literal arms "race" between herbivores and carnivores. With open space and little cover, running became a vital survival skill. Today's antelope and cheetahs, which can run as fast as cars, are the result of tens of millions of years of chase on the African plains. Our primate ancestors were preyed upon by large cats and creodonts as well as snakes and birds of prey. [14]

Marine life also experienced sea changes in this time scale. The most important new marine ecosystem was the kelp forest, which thrived in shallow seas. [15] Whales and marine birds were at their most diverse during the Neogene. Newly evolved sea animals included seals, otters, and penguins.

III. Fossil Apes

A. From Monkeys to Apes

If you saw your catarrhine ancestors from 30 million years ago, you would most likely call them "monkeys". Monkeys are relatively small animals, on average about the size of cats. They run along the tops of large tree branches on all four limbs, palms down, and leap from branch to branch. Their arm and leg joints have limited motion. A monkey's tail acts as a fifth limb; it is long and prehensile and good at grabbing objects or hanging from branches.

The African catarrhine line of descent diverged into the lines that would become "Old World monkeys" and apes 25 – 30 million years ago. [16] Examples of living Old World monkeys include macaque monkeys, proboscis monkeys, and the unusually large baboons. We are descended from the ape side of the family, which today includes animals ranging in size from the gibbon to the gorilla. The technical term for our earliest ape ancestors is the basal *hominoids*, but they are just as often called ***fossil apes*** or *dental apes*, because their teeth were among the first features to distinguish them from monkeys.

What are the differences between monkeys and apes? Some differences are a matter of degree: most apes are larger than most monkeys, and ape skulls and brains are relatively larger compared to their bodies. There are other important differences in body structure. Apes do not have tails. Apes have more flexible arms, wrists, and shoulders and more prehensile hands and feet, allowing for a greater range of postures and locomotion than monkeys. When in trees, apes hang downward from branches by their hands and / or feet, and some of them swing or ***brachiate*** acrobatically from branch to branch. This last fact is a common point of confusion because we are all familiar with "monkey bars" on the playground. That name is a misnomer. They should be called "ape bars"! All apes *can* brachiate; Asian apes rely on it as their primary mode of locomotion. [17]

The monkey / ape divergence must have been the result of some environmental condition or competition. One leading hypothesis contends that the pressure was scarcity of their favorite food, ripe fruit. Monkeys dealt with this by settling for second best; they evolved sharper teeth and digestive systems for eating leaves and unripe fruit. Apes continued to pursue ripe fruit, but they had to work harder to get it. [18] In particular, apes made more use of their arms in the trees and

their legs on the ground. Their skeletal features made them good at climbing, hanging, and swinging by their arms. [19] Their strong, flexible arms and hands were one of their most important contributions to our bodies. [20] Perhaps the absence of a tail favored the evolution of prehensile hands.

Fossil apes continued to share tropical rain forests with monkeys. [21] Because apes were choosier in their diets, though, they were restricted to smaller geographic regions [22] and different niches. Their larger size gave apes a slight advantage in covering more ground between trees.

Full "apification" took tens of millions of years. The oldest known fossil apes lived 20 – 25 million years ago. [23] The earliest species had opposable big toes and had already lost their tails, but otherwise their bodies were still monkey-like. The earliest clear evidence of arm-hanging apes did not appear until 12 million years ago, and brachiation was perfected even more recently. [24]

B. The Uniquely Human Clade

Some ape populations migrated out of Africa and spread throughout Europe and Asia at least 17 million years ago. The global temperature was still about 5º C warmer than it is now. [25] Apes' habitats, dense rain forests, thrived as far north as Europe.

Now that apes occupied a broad geographic range, they evolved into suitably diverse forms. The Neogene was a golden age for apes, with many more species than today. Our ancestors grew larger bodies and brains and became the Linnaean family of *hominids* or ***great apes***, as distinguished from lesser apes such as today's gibbons. Only one great ape, the orangutan, survives in Asia today. None survived the Neogene in Europe, as their forest habitat could not survive the cooling climate. The rest of them returned or continued to live in Africa. An interesting debate concerns the question of whether our ancestors were among the temporarily European apes [26] or if they remained in Africa the whole time. [27] This is only one such "Out of Africa" question that arises occasionally in pre-*sapiens* genealogy. Among the apes that ended up in Africa, three genera have survived to the present. Gorillas branched off from this family tree about ten million years ago.

Then a process occurred that went completely unnoticed at the time, although it seems monumental from today's perspective. Seven to ten million years ago, * [28] one special population of African apes separated into two. One of those sub-populations ultimately evolved into chimpanzees. The other one was the unique forerunner of the human species! Unfortunately, there are few fossils available from that place and time. We do not know exactly what the last common ancestor of chimpanzees and humans looked like. We would not expect it to look just like a modern human or a chimp, since both species have changed since then. The general consensus is that it still lived in trees and looked more like a chimp or a gorilla than a modern human. [29]

Except for some overlap in the ranges of gorillas and chimpanzees, the three African apes settled in different regions. Gorillas and chimps inhabited western and central Africa, [30] while human ancestors took to the east and then the south. [31] The features distinguishing gorillas, chimpanzees, and humans were influenced by their habitats. Gorillas, for instance, occupy only a few small patches of rain forest near the equator. Their sharp molars and large guts are adaptations to a diet heavy in leaves. [32] Humans emerged in Africa's most arid, temperate regions. That process will of course be explored much further below.

Were the East African apes of the late Neogene "humans"? That would be a fair label. Although they looked like animals that we'd put in the zoo today, they were our unshared ancestors. They could certainly not be classified as any other living animal. † We are mentally biased, though, by the way humans and other animals appear today. Most of us reserve the word "human" for our more recent ancestors who looked and behaved more like us than like chimpanzees. To satisfy that instinct, our unique ancestors of 2 – 7 million years ago are given the special name "hominins". It all goes to show that even a word like "human" is truly impossible to define.

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* Pinpointing the human / chimp divergence is a surprisingly difficult and cutting-edge area of research. Evidence for genetic divergence ranges fairly wildly from 4 – 13 MYA, with the middle of that time frame, 7 – 10 MYA, being the most common estimate. A genetic divergence of 13 MYA is furthermore consistent with a genealogical split of 7 – 10 MYA (see citation).

† Not that there is anything categorically special about animals "living today". There are several extinct human species, and if one of them still survived then our species' unique ancestry would be much more recent. If chimps went extinct, then suddenly our unshared ancestors would date back to the gorilla split.

IV. Hominins

Late in the Neogene Period, the African landscape was making a gradual transition from forest to grasslands. The Ethiopian Highlands cast a rain shadow over the Great Rift Valley. [33] Hominins flourished there in mixed ecosystems of woods, savannas, and the shores of lakes and rivers. In this setting, they acquired two key anatomical features that distinguish humans from our cousin apes: bipedalism and the loss of fangs.

A. Walking Tall

The human form of ***bipedalism***, walking on two legs, is one of the most striking characteristics to distinguish us from other apes, and one of the first to evolve. It was the precursor of evolutionary revolutions to come. The full description of our form of locomotion is ***obligate erect*** bipedalism. Other apes *can* and *do* sometimes walk on two legs, but it is not optimal for them. Think of a chimp's awkward waddle or a gibbon's much greater ease in the trees. Humans *must* walk bipedally because it is the most efficient way for us to get around – that's the "obligate" part. Furthermore, our two-legged gait differs from other apes'. When chimps and gorillas walk on their hind feet, they are usually stooped with bent hips and knees. Humans maintain an erect posture. Thus, the evolution of our gait involved these three qualities: walking bipedally, keeping an upright spine, and doing it more gracefully than other forms of locomotion. As with most complex systems, the components came together gradually over millions of years.

The very capacity for bipedalism is probably almost as old as apes themselves, and has its roots in the trees. All living apes retain it. Arboreal apes use their arms to reach for branches overhead, but at the same time they use their feet to stand on boughs below. [34] The biomechanics of walking also bears some resemblance to the use of legs in climbing trees vertically. [35] As open spaces between the woods expanded, hominins took bipedalism and ran with it. [*]

Obligate erect bipedalism required modifications to almost the entire skeleton, from the skull to the soles of the feet. For erect posture, the hole where the spine enters the skull migrated from the back of the skull (as in chimpanzees) to the bottom of the skull. The lower spine arched

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[*] Puns intended. Sorry!

forward, and the knees bent inward, to keep the body's support axis aligned with its center of gravity. The pelvis became much broader and squatter. The hips and knees became fully extendable, and the ankles more rigid. The feet transformed into a uniquely human structure. If you look closely at any other ape, you will notice that its feet look like hands. They have flat palm-like soles and an opposable thumb-like big toe. Those organs are good for grabbing onto branches or vines for support in the trees. Human feet are made for walking and running on the ground. The forward-pointing big toe provides great strength for balancing and stepping off, while the arches put a spring in our step.

The details of exactly when and why these traits developed are still being refined. [36] It is safe to say that they roughly paralleled the opening of the African plains. Grasslands started to appear in eastern Africa ten million years ago, and they impinged on woodlands exponentially until they dominated the terrain by 2 MYA. [37] The earliest evidence of erect bipedalism dates to the middle of this ecological transformation, 7 MYA. [38] Our ancestors of 3 – 7 MYA were hybrid walkers and tree climbers with short legs. [39] By the time the trees thinned out significantly, hominins had a long-legged striding gait well suited to open spaces.

The advantages of obligate erect bipedalism seem clear to us today. Walking could have permitted hominins to increase their foraging range, carry food around, and / or reach fruit high in bushes that they couldn't climb. Upright posture is energy efficient, as it keeps all of our weight supported on strong legs and feet with minimal muscular effort for balance. This anatomy enabled the growth of a heavier brain in the Chapter 6 time scale. Erect posture also liberated the arms to specialize in different functions divorced from locomotion.

In evolution, there is no such thing as a free lunch. Bipedalism bears costs as well as benefits. Bipeds are slower than obligate quadrupeds. We are vulnerable to injuries of the knees, feet, and lower back. Circulating blood from the legs back to the heart is also a difficult physiological challenge. On balance, though, apparently these drawbacks were outweighed by the advantages, as bipedal hominins not only survived but thrived.

B. No Fangs, We're Hominin

Teeth are the most thoroughly studied body part of all fossil animals, in large part because they are the hardest, best preserved anatomy. They have evolved into an endless variety of patterns

that serve almost like fingerprints to identify species. Teeth reveal valuable insights about diet as well as behavior.

Besides erect bipedalism, the other uniquely human feature that shows up early in the hominin record is non-beastly teeth. From gibbons to gorillas, all other living apes sport large "fang" canines. Only humans have non-projecting canines, with uniform rows of teeth. There is some debate about whether human ancestors once had large canines, which were then reduced, or if our line of descent never had fangs at all. [40] It seems highly likely that fangs were in our ancestral past at some point, as they are present in all other living apes and Old World monkeys. One way or the other, hominins came to be the exceptional ape with small canines.

Non-human apes have a special chewing feature called ***honing***. Every time such an ape bites down, the back edge of an upper canine scrapes against the front edge of a lower pre-molar. This friction whets the canine and keeps it sharp like a blade. There is a special gap in the lower teeth to accommodate the canine when the mouth is closed (and likewise for the lower canines, all in reverse).

Ape canines are much larger than their diets alone would dictate. Carnivores use their fangs to take down large prey. Up to the time of the human / chimpanzee split, though, apes were almost strictly herbivores. Apes use their canines primarily for fighting. Sometimes they defend against predators. Males often use or bare their teeth against each other in contests for females. In such species, natural selection favors a more vicious display, and the canine teeth have evolved to greater size in males than in females. This is an example of ***sexual dimorphism***.

From early hominin times, canines have been smaller and less dimorphic, and have lacked the honing mechanism. [41] Instead, our canines are utilized like incisors, and they get worn down at the tip when we chew. The gap in the opposing jaw mostly disappeared by 3 MYA. [42] By then, canines had achieved their present shape and size – not only small, but the same size for the two sexes.

This dental makeover was pretty significant, and it is striking that it happened only in our lineage. Like bipedalism, the exact reason for our ancestors' defanging is still unknown. There are two classes of feasible explanations: Either hominins found value in using small canines to chew their food, or they no longer needed them for defense and competition. These hypotheses are not mutually exclusive, and in fact no single-cause model seems sufficient to account for the change. [43]

To support the dietary hypothesis, we can look to other changes in dentition and diet. Concurrent evolutionary trends included thicker enamel and a more vertical orientation of chewing muscles. [44] This suggests that hominins were eating hard foods such as seeds, grains, and nuts, which are crushed by flat molars. [45] They also ate an increasing amount of fleshy grass-root vegetables after 3.5 MYA. [46] Some species developed smaller mouths and larger molars [47] that would have crowded out large canines; many people today still need wisdom teeth removed. These demands on teeth could have pressured the more efficient use of canines as reduced chewing instruments.

Grasses and roots, like the fleshy corm of this Crocosmia plant native to eastern Africa, helped hominins survive outside of lush forests. They also may have promoted the reduction of canines to serve a greater role in biting and chewing.

Roots such as bulbs and tubers (think onions and potatoes) might have been a real game-changer. [48] They evolved to preserve water, a function necessary in woodlands but not in tropical forests. Roots are conveniently buried underground, safe from competitive foragers. Apes that could use short canines to puncture and chew would have a real advantage. [*] Tubers called *corms* are abundant in eastern Africa and might have been a staple of the hominin diet.

The reduction of canines is also most likely associated with their function as weapons and threats. Among living primate species, those with the least dimorphic canines are those with the least male-male competition. [49] If this was a factor for early hominin canine reduction, then it could signal major changes in sexuality and social structure, which will be further expanded in Section V and Chapter 6. Hominins retained body-size dimorphism, indicating that males were still competitive on the basis of size and strength. It is even possible

[*] As would apes who could dig with tools!

that canines became less useful against competitors and predators as hominins stood upright and could throw rocks! [50]

The way you walk, the way you smile: these are the two most primitive qualities that make humans unlike any other species on Earth.

C. Grandma Lucy and Other Hominins of Note

Most of our evidence about extinct hominins comes from fossils. Unfortunately, our ape ancestors were denizens of the jungle, and tropical forests are notoriously unfavorable for fossil preservation. When an animal dies in a forest, it falls on solid ground and is immediately vulnerable to weathering and all sorts of decomposing agents, from bacteria to scavengers. For this reason, there are major gaps in the fossil ape record, including the anthropological Holy Grail, the point of human / chimp speciation.

Nevertheless, paleontologists have found remains of several hominin species, with enough diversity to categorize them into more than one genus. Some of these fossil finds are unique or especially complete, so they have become the standard bearers of this phase of evolutionary history. Scientists currently recognize at least four hominin genera that preceded *Homo* and are fair candidates for human ancestry.

The oldest known potential hominin is *Sahelanthropus* (Chad, 6 - 7 MYA). This genus is known from some teeth / jaw bones and one skull, from a presumably male specimen named Toumai ("Hope of Life"). Without a body skeleton, the evidence for bipedalism is indirect but reasonable: the spine apparently entered the base of the skull, [51] a configuration that is only found in hominins. Toumai also had non-honing canines, which were intermediate in size between humans' and chimpanzees'. [52] This evidence is still being debated, but, if corroborated, it projects the hominin story millions of years and thousands of kilometers from other known fossils.

The densest region for hominin fossils is the Rift Valley, which cuts through Ethiopia, Kenya, and Tanzania in eastern Africa. The *Orrorin* genus was found here (Kenya, 6 MYA). In some ways – its thigh bones, small molars, and large body size – *Orrorin* was more like modern humans than some younger genera. It still bore many characteristics of fossil apes. *Orrorin* was a tree dweller with curved fingers and ape-like, medium-sized canines. Its thighs indicate that it was

probably capable of bipedalism. The honing complex is "reduced" compared to older species, but is actually similar to a female chimpanzee. [53]

Ardipithecus roamed the woods of Ethiopia 4 – 6 MYA. Hundreds of individuals have been found. The most famous and complete one is a female named Ardi. Ardi was another hybrid biped / tree climber, with unique forms of hands and feet. With features found in neither humans nor chimpanzees, she presents evidence that the human / chimp common ancestor was also not exactly like either one of us. [54] *Ardipithecus* exhibited a low degree of sexual dimorphism, suggesting a reduced level of male competition. [55]

The most recent pre-human genus, *Australopithecus,* is the best known. This was a widespread and well-preserved genus, known to range through central, eastern, and southern Africa 1 – 4 MYA. Its premier ambassador is Lucy, a four-foot tall, 3 MY old female *Australopithecus afarensis* from Ethiopia. Lucy was a media sensation, the oldest and most complete hominin fossil found to date in 1974. She was irrefutably bipedal.

One of the most haunting fossils is a trail of footprints in Laetoli, Tanzania. Following a nearby volcanic eruption and a rain, an impressionable layer of ashen mud covered the ground. As on a wet sidewalk, footprints record that day's traversal of several animals, including cats, dogs, hoofed animals – and five hominins. Their 4 MY old feet, presumably australopithecine, were surprisingly similar to ours, with arches and forward-pointing big toes.

A mysterious 3.5 MYO skull from Kenya raises intriguing questions. It might represent a fifth genus, *Kenyanthropus*, with a human-like flat face instead of a snout. It is hard to tell, because the fossil is distorted. [56] There is also controversial evidence that *Kenyanthropus* was capable of chipping stones into tools. [57] If it is not an *Australopithecus,* then this was the first time that two hominins were known to co-exist. A hominin radiation did begin around this time. *Australopithecus* species after 4 MYA were adapted to more diverse habitats and diets than earlier woodland apes. [58]

Discovery and analysis of hominin fossils is an active field at this time. [59] Scientists can't resist charting the known specimens into a phylogenetic tree leading to humans, though this is impossible at the species level. [*] *Australopithecus* is known to overlap with *Homo* in place and time, and it has long been regarded as our parent genus. [60] Now the older genera, all discovered

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[*] As attested by the fact that no two proposed trees are alike!

after 1990, provide a few tantalizing glimpses of what our early hominin ancestors might have looked like.

V. Our Ape Nature

After fossils, our secondary sources of evidence about hominin ancestors are our closest living cousins, the great apes. We can directly observe apes' soft-tissue anatomy (flesh, organs, cell biology) as well as their behavior. It can be informative to assess how humans are similar or different from chimpanzees and the other great apes. It is a reasonable conclusion that we inherited or adopted our shared characteristics from a common ancestor ten million years ago. The qualities that distinguish us from chimpanzees were most likely derived after our speciation. It is difficult to date these changes. As a practicality, this section will focus on the elements of human nature that we share with other apes. Chapter 6 will discuss adaptations that occurred only within the hominin / human line.

A. Changes by Degree

Some evolutionary developments of the last ten million years have been continuing trends and matters of degree. Apes continued to evolve larger bodies and brains. They lived in increasingly large and complex social groups. They lived longer and had fewer children with prolonged childhoods. Chimpanzees eat a modest amount of meat, suggesting some carnivory many millions of years ago.

Human and chimpanzee DNA are 96% identical. [61] * Of the 4% difference, most likely each species has deviated only about 2% from our common ancestor. Genetically, then, hominins were already 98% human at the time of speciation almost ten million years ago! Since the intervening genetic change has been so numerically modest, we must reach one of two conclusions. Either some of our most recent mutations were extraordinary breakthroughs, and / or our most

* Quotes for this figure do not all agree, because "similarity" can be measured in multiple ways. Only about 1% of the difference is due to completely different base pairs. The other 3% is due to different repetitions of the same genetic material. Further, two chromosomes fused together in humans after the speciation, so humans now have 23 chromosomes as compared to 24 for the other great apes.

extraordinary characteristics are not entirely genetic. Human social structure could have brought out capabilities that were already latent in human / chimp ancestors.

B. Brain and Intelligence

A type of brain cell called the ***spindle neuron*** is found in all great apes, but not lesser apes or monkeys. [*] This indicates that the cell evolved approximately 15 – 20 million years ago, between the speciation of gibbons and orangutans. Spindle neurons are large, allowing them to convey signals quickly. They may have originally been an adaptation for physically large brains, as they evolved independently in a few other large animals such as elephants and whales. Then perhaps their ability to communicate rapidly with other parts of the brain got "co-opted" for social intelligence. [62]

Spindle neuron research is relatively new, and the field is pregnant with exciting hypotheses. The cause for the clamor is that these cells are found only among large-brained mammals with high levels of self-consciousness, empathy, and social coordination. Furthermore, the areas of the brain that are rich in spindle neurons are specifically active in emotional maturity, social skills, and higher thinking. For example, some spindle neurons connect an area of the brain that determines when a mistake is being made to another part involved in memory and planning. This integration of past, present, and future could contribute greatly to learning and volition. [63] The cerebellum, the part of the brain responsible for coordinating voluntary movement, also experienced a growth explosion in great apes. [64] The cerebellum organizes refined motor skills such as swinging through trees, foraging across large ranges, using tools, throwing, and speaking.

With such advanced brain anatomy, apes have demonstrated a capacity for several higher forms of learning and "civilized" behavior beyond other animals. Chimps and bonobos are more "patient" than other animals, more willing to forego a smaller immediate reward for a larger future reward. [65] Other examples are detailed below.

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[*] With the exception of low density spindle neurons in the macaque, an Old World monkey.

C. Tool Use

Mechanical intelligence is an understanding of how inanimate objects work. It includes concepts such as *object permanence*, the property that an object will persist in time even when the observer does not see it. Only great apes have demonstrated a true understanding of mechanical cause-and-effect. We believe that apes alone can form mental representations of physical objects. [66]

Only after an animal understands objects can it manipulate them into tools for specific uses. Common chimpanzees have a proven track record at using and modifying natural objects for personalized purposes. Certain populations of chimps routinely use sticks to go "fishing" for ants or termites, and they even streamline the sticks by removing side branches. They use rocks to crack nuts and leaves as sponges to soak up water. Captive chimps can solve a problem with "insight" such as putting two short sticks together to form a long stick to reach food. [67] No other great apes use tools in the wild, though human keepers have taught a few bonobos and orangutans to use and even make tools.

The creation of stone tools, flakes, was a milestone breakthrough in hominin history. Flakes were not widespread before 3MYA, but some flakes 3.3 MYO have been found in the vicinity of *Kenyanthropus* fossils. [68]

D. Linguistic Potential

While no other apes are in command of true language, they do exhibit some of the mental modules and brain structures that facilitate language. This would suggest that our earliest hominin ancestors were endowed with linguistic potential, which was further developed in more recent times.

The capacity for language can be broken down into distinct mental and social skills. The most obvious one is symbolism, the recognition that a sound or sign can represent something else. Symbolism is built upon the more fundamental skill of perceiving concepts; a sign for "large" is meaningless until an animal understands the essence of "largeness".

Apes are able to form mental concepts, not only for concrete terms like "ball" but for abstract properties such as "large" and "same". [69] [70] Researchers have even had luck teaching words to a few individual apes in captivity. Koko the gorilla could sign 1,000 learned words and

form new compound words. [71] Kanzi the bonobo has a similar vocabulary of lexigrams. [*] Both comprehend spoken English. Apes in some communities gesture to each other [72] or use distinguishable grunts for different types of food. [73]

Clearly some, but not all, capabilities in our language skill set were already present in our ape ancestors. The language centers of the human brain are asymmetrically located in the dominant (usually left) hemisphere of the brain. Chimpanzee brains are slightly asymmetric in the same regions. [74]

Non-human apes are physically incapable of speech. Our hominin ancestors had to modify their throat structure in addition to losing their fangs and snouts. These changes were showing signs of progress already in *Ardipithecus* over 4MYA, [75] most likely for reasons unrelated to speech.

E. Inner Angels: Morality

We humans often tell ourselves that our morality sets us apart from the other animals. Creation stories made it very clear-cut: we were made differently, infused with God's wisdom. Unless we take mythology literally, we have to wonder when and how our morality evolved.

What is morality, anyway? It can be defined as respect for others' feelings, rights, and situations, without clear benefits to oneself. Before animals can be moral, therefore, they must be capable of conceptualizing that others *have* feelings, rights, and situations that differ from their own. They must have a ***theory of mind***. [76] Fascinating research suggests that apes possess a theory of mind that is much more developed than monkeys'.

In the lab, scientists measure morality one small, objective step at a time. Theory of mind was first defined in mirror self-recognition experiments. The idea is that a mirror provides a subject with a representation of herself from someone else's perspective. Only if she fathoms this outside perspective will it occur to her to identify her reflection with her sense of self. Monkeys understand mirrors, [77] yet they still don't "get" their own reflections. [78] Chimps and orangutans consistently display mirror self-recognition, [79] as do other species with spindle neurons! [80] [81] Chimps can also distinguish accident from deliberate bad intent [82] , comprehend that people in a

[*] Koko and Kanzi both lived in captivity in the US in 2000; Kanzi was still alive as of this writing in 2019.

room know things that outsiders don't, [83] and reverse roles in cooperative games. [84] The cumulative signs indicate that theory of mind originated in our ape ancestors.

Understanding someone else's situation is not only a great leap forward in cognizance, but the starting point of moral choices. It can be used sympathetically to assist others, or exploited for personal gain. Apes take both approaches. One chimpanzee can discern what another is striving for, and provide help targeted toward that need. [85] Chimps console losers after fights. [86] Apes regularly treat other group members well, beyond the bounds of kinship and reciprocity.

Acting for the common good has obvious survival advantages for strongly social animals. A group that bands together is better at gathering food and defending its members from predators and enemies. Since gorillas, chimpanzees, and humans are always found in complex social groups, [*] it is likely that our morals began to develop in our common ancestors, Neogene African apes.

F. The Social Male

Ape species have settled into diverse social patterns, especially when it comes to gender relations. Gibbons associate pair-wise as faithfully monogamous couples. Orangutans are even less social, loners of the jungle. A gorilla community is essentially a harem, with as few as one adult male, numerous females, and their offspring.

Chimpanzees are unusual in having communities with large numbers of males. Male-male social integration is found only in a few other primates and very rarely in other mammals. However, it is absolutely definitive to the nature of the chimpanzee and its closest relative, the human.

The chimpanzee genus, *Pan*, includes the "common" chimp, *Pan troglodytes*, and the bonobo, *Pan paniscus*. The social differences between these species make a compelling case study. Bonobos are female-dominated, with each male inheriting his mother's status. Maybe because of this motherly presence, bonobo communities are generally more peaceful and stable. Bonobos are also notoriously sexual, cementing community bonds with sex play as well as offspring. *P. troglodytes* is a male-dominated species, with males constantly jockeying for power.

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[*] As opposed to herd animals (like cattle or fish) which can travel in very large groups but do not exhibit interpersonal relationships based on social status or shared and remembered experiences.

Alpha male status is not a birthright for chimps. It is a revolving throne held at most for five years at a time. [87] Since the alpha male gets his pick of mates, males fight dearly for the title.

If the story ended there, it wouldn't be very interesting. No alpha male can hold the throne with brute strength, because fights are rarely one-on-one. Power struggles are waged by alliances. Male chimps spend their lifetimes cultivating friends to outnumber enemies. A chimp community has as much political intrigue as any king's court. [88]

When the "throne" is stable, a chimp community is characterized by male-male cooperation. Stability is especially important for purposes of hunting and defense. Chimps are among the few animals that hunt in coordinated packs. A team of males will scout together and sometimes team up to trap prey. This behavior should all sound very familiar. It is impossible to imagine human culture without men competing or cooperating.

G. Inner Demons: Rape and Murder

It's always been a jungle out there. But with the cunning brain power and social-male communities of chimps and humans, a new kind of evil emerged, a calculated violence against fellow species members. Three striking crimes perpetrated by apes are murder, rape, and ***lethal raiding***. In nature, they are usually desperate measures by males for access to sex. [*]

Chimpanzee morality is strictly an in-group sentiment. Communities normally max out at about 100 – 120 individuals, possibly limited by the number of social relations they can mentally process. [89] Outsiders are seen as competitors, and emotional bonds do not extend to them. Not only do chimps defend their own territories, but they sometimes offensively raid a neighboring territory. When a group encounters a lone "foreign" male, it occasionally gangs up to kill him. These killings are brutal, similar to hunts. Over time, a population of chimps can completely wipe out all the males of a neighboring group and take over its territory. [90] "Chimpicide" increases the victors' access to females, as females emigrate from surrounding communities and are attracted to groups with more males. [91]

[*] When targeted against adults. Females sometimes commit infanticide for different reasons.

Males of a population are all related. Beyond the stable size limit, though, they fail to recognize each other as relatives, and splinter into "foreign" or even "enemy" groups. [*] [92] By contrast, bonobo communities will inter-mate, creating a larger extended family and maintaining moral equivalence. [93]

Even within a population, chimp politics sometimes leads to murder. In most species, male competition is a display of intimidation. Fights progress to the point of exhaustion and surrender. [94] In rare occasions when sexual competition is intense, chimps will conspire to murder one of their own. In 2017, the ninth known chimpanzee assassination was documented, and the details read like a horror story. [95]

Rape is surprisingly rare throughout the animal kingdom, but it is practiced by non-dominant male chimps when the alpha male withholds females. [96] Chimps have also kidnapped and raped females from conquered tribes. [97] Orangutans, which lack female support networks, rape routinely. [98]

What can ape violence teach us about humans? "Natural" human communities are not much larger than chimps', and humans, like chimps, never evolved a moral instinct toward outsiders. [†] Group splintering, raids, and female kidnapping / rape in human hunter-gatherer society are strikingly similar to chimp behavior. [99] Lethal raiding is not "war", but both are emotionally justified by xenophobia. On the other hand, human tribes also adopt a bonobo-like strategy of inter-marriage for peaceful integration.

Ironically, conflict breeds cooperation. Antagonism from outsiders has been a critical pressure for in-group coherence. [100] The ever-present threat of rape fosters defensive female cohorts, and male politics serves as a constant check against tyranny. There's no denying that human good and evil evolved inextricably together.

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[*] The famous Gombe chimpanzee war of the 1970s was fought between two rival factions that had started out within one community. Jane Goodall wrote about chimps who had grown up as friends murdering each other aggressively.

[†] The Hebrew's 1st commandment "You shall not kill" lacked an object ("We shall not kill whom?!") and apparently didn't need one because the Hebrews took for granted that it applied only among themselves. Other passages in the bible such as Deuteronomy 2:34 and 20:16-18, Joshua 10:40, and 1st Samuel 15 informed Hebrews that it was acceptable and even desirable to kill foreigners. Criminal laws historically only forbade crimes against the jurisdiction's own people, and to this day human rights enforcement is left up to each nation for its own citizens.

VI. Summary

Over the last few tens of millions of years, primates evolved into apes. Apes are identified by a few physical characteristics making them different from monkeys. They are especially notable for their arms, which are adapted for hanging and swinging from branches. Most apes share rain forests with monkeys, but occupy slightly different niches. Despite their greater size, apes' suspensory behavior gives them advantages in the treetops.

Socially, apes continued to evolve in the direction of having larger social groups but fewer children with longer lifespans. The great apes developed larger brains with spindle neurons, unique brain cells associated with social intelligence and self-awareness. An enlarged cerebellum enabled greater motor abilities.

The Neogene Period, 23 to 3 million years ago, was a veritable age of apes, with tens of species enjoying incredible success across Africa, Asia, and Europe. Their habitat shrank significantly when the Earth experienced a permanent trend of drying and cooling. Forests receded to the equatorial regions, and apes left Europe to follow the forests. Only five small genera of apes remain today. Four of them continue to dwell in rain forests of Africa and Asia. They are highly specialized for that ecosystem, and have accordingly limited habitats.

The fifth ape, hominins, tried a different strategy. They forged into the cooler, drier habitats of eastern and southern Africa. Hominins diverged from a common ancestor with chimpanzees at some controversially-dated point of time on the order of ten million years ago. For unknown reasons, they had already started to develop unique traits such as erect bipedalism and reduced canines. Those physical features proved to be advantageous in woodlands and savannas. Hominins found a valuable new source of nutrition in roots. They also ate seeds, nuts, and probably even some meat.

Hominins, of course, were human ancestors. Instinctively, we do not yet honor the earliest hominins with the label "human". There are legitimate biological reasons for this distinction, but these ancestors had reached the point of separating us from the rest of the animal kingdom. The best-known and most recent hominin genus was *Australopithecus*, which arose four million years ago. Australopithecine apes were curiously hybrid ground-walkers / tree-climbers about the size of modern chimpanzees.

Great apes have a theory of mind; we are able to conceive of other minds as having different perspectives from our own. This makes social life infinitely more complex. We can see past our differences and cooperate for a greater good. At the same time, we can also lie, cheat, and take advantage of each other. Since we relate to each other as individuals but can only accommodate a limited number of relationships, ape morality draws a sharp distinction between an in-group and out-groups. In chimpanzees and humans, this effect is complicated by a unique social structure with multiple males. Competition occasionally leads to deliberate acts of murder, even within a community.

The point of hominin speciation is a special juncture in our ancestral history. It is a moment to speculate about the dichotomy of human nature. We are inherently animalistic, but we are also so clearly unique.

VII. Ancestor Gallery

Some of the best paleoart is from the Chapter 7 timescale, including lifelike sculptures and masks of fossil apes. For the art that is copyrighted, I provide links to the best available photos.

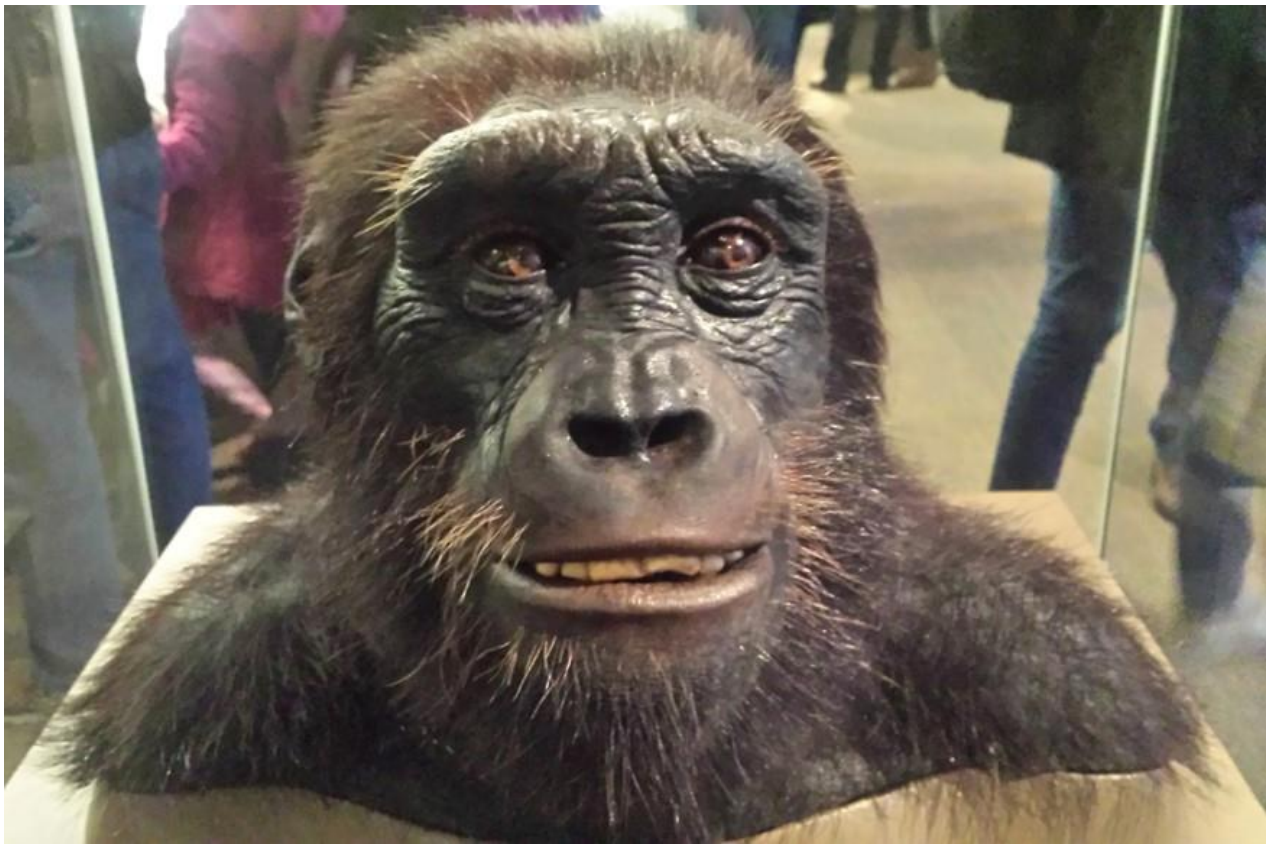
Monkeys such as *Aegyptopithecus* were basal catarrhines about 30 MYA. They were found strictly in Africa, which at that time was isolated from Eurasia. [101]

The earliest known animal considered to be an ape is *Rukwapithecus*, which was found in Africa 25 MYA. This image of *Rukwapithecus* appears to be copyrighted, so I can not show it here. Today's apes include orangutans and gibbons in Asia, gorillas and chimpanzees in Africa, and humans.

Proconsul was one of the earliest fossil apes, thriving in eastern Africa 20 MYA. We know it's an ape by its lack of tail. Its teeth were becoming ape-like. Otherwise, its body was very monkey-like in size and form. [102]

The golden age of apes was the mid-Neogene of 12 - 17 MYA, when climate was warmer and some species migrated to Europe and Asia. The upper body went through modifications for hanging rather than walking on branches, while the lower body was starting to allow for some upright postures. [103] Our mid-Neogene ancestors were the first great apes, closer in size to chimpanzees than gibbons. This reconstructed specimen, "Pau", lived 13 MYA in Spain . [104]

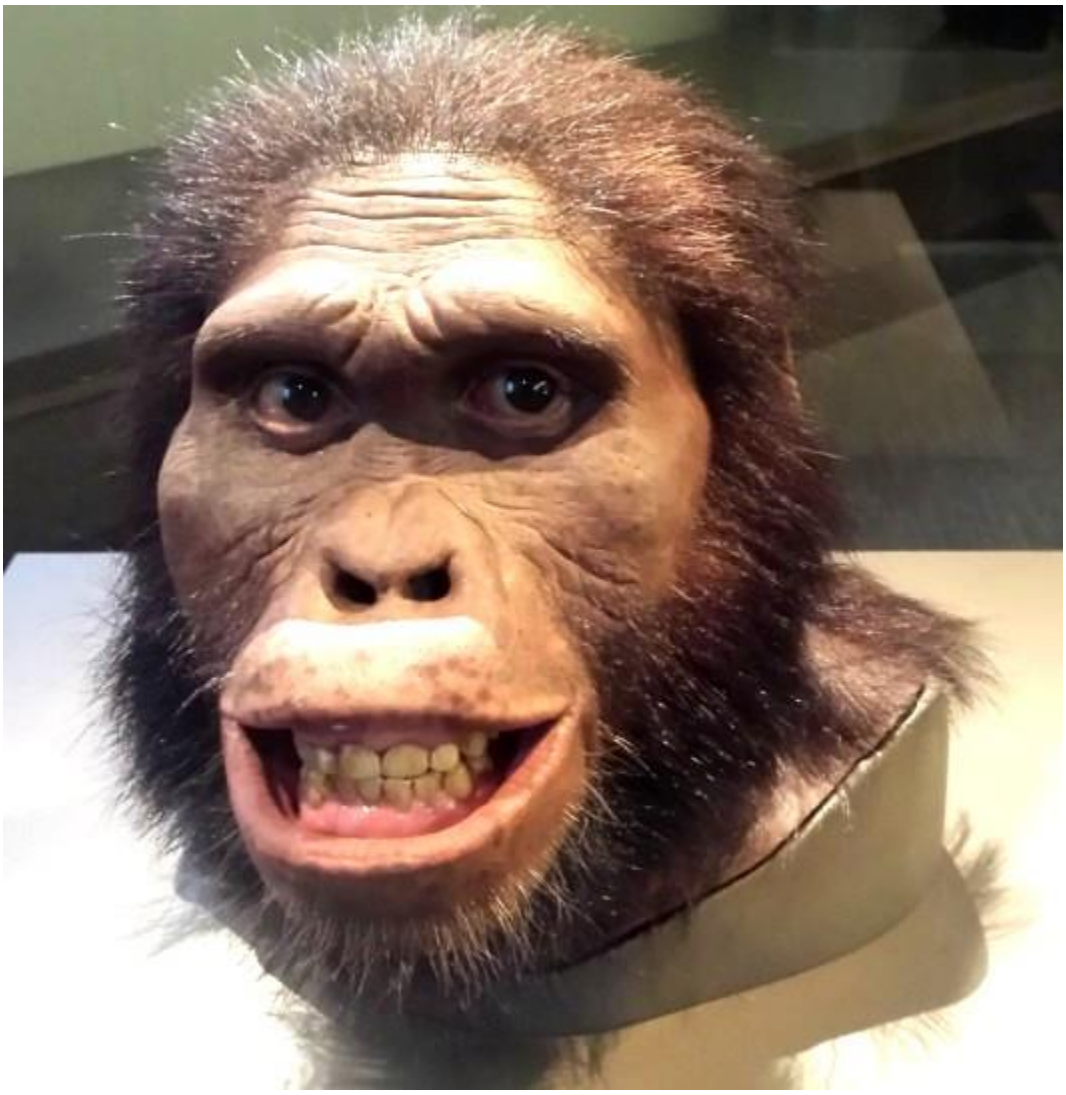
By 7 MYA, apes such as "Toumai" (a *Sahelanthropus*) showed evidence of erect bipedalism and smaller canines, good indications that they were closer to humans than to any other living ape. [105]



"Ardi", an *Ardipithecus* from 4 MYA, is one of the most famous 21st-century fossil discoveries. Ardi's authoritative portrait is copyrighted. I encourage you to click the drawing to see her full body. Her appearance is strikingly human-but-not-human, like something you'd except in a *Planet of the Apes* movie.

The *Australopithecus* genus evolved in eastern Africa about 4 MYA and survived until the appearance of *Homo* 2 MYA. *Australopithecus* is widely assumed to be *Homo's* parent genus. There were several *Australopithecus* species. The one shown here is *A. afarensis* (Ethiopia, Kenya, and Tanzania c. 3 - 4 MYA), the most well-known due to its highly complete representative fossil specimen, "Lucy". [106]

Australopithecus africanus lived 3 MYA in South Africa. [107]



By this time, Australopithecines were about 99% genetically human. These ancestors fascinate us because they represent the transition from wild animals to modern humanity. They walked upright on feet very much like ours. They were still semi-arboreal and smaller than humans. Their faces had pronounced snouts. Culturally, they probably behaved more like chimps than humans. They may have been in the early stages of flaking stone tools.

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