Chapter 10^6: THE LAST FEW MILLION YEARS
(3 Million – 300,000 Years Ago)

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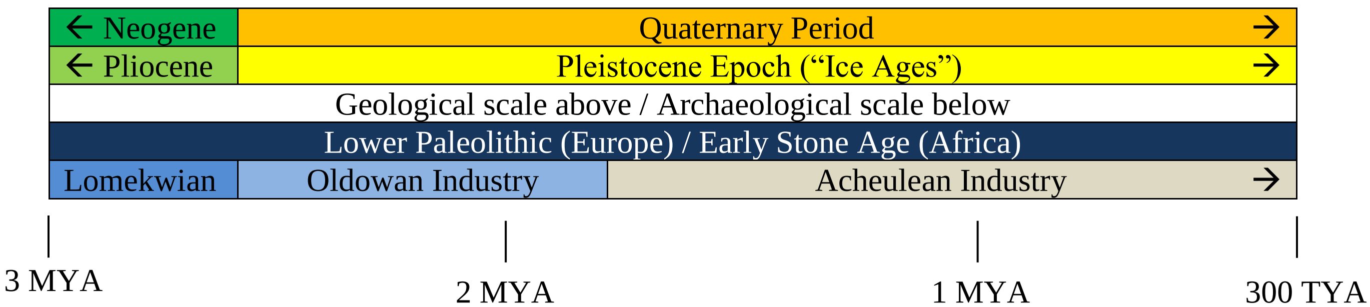
I. Introduction and Geological / Archaeological Terms

Welcome to Chapter 6, the world of a million years ago. We are now holding one gold bar of time in our hands. It's time to learn another round of technical terms. The present-day geological period is called the ***Quaternary***. The lengthy first epoch of the Quaternary, the ***Pleistocene Epoch***, lasted from 2.6 MYA all the way up to Chapter 4. These terms no longer gibe very well with their etymologies. The term "Quaternary" originally meant "fourth" and "Pleistocene" meant "the most recent". Now they have both been redefined to coincide with Earth's current cycle of ice ages.



For the first time in Chapter 6, we encounter time scales that are used by archaeologists instead of geologists. Archaeology is the study of humans and their artifacts. In fact, archaeologists define "humans" as distinct from earlier hominin animals by their use of tools. The first tools were made of stone, so the earliest archaeological age is called the ***Stone Age***, or in Latin -***lithic***. The Stone Age is much longer than scientists realized when they first named it, so it has been divided and subdivided many times over. The oldest part of the Stone Age is called the ***Paleolithic***, which itself has lower, middle, and upper stages. Chapter 6 coincides almost perfectly with the lower Paleolithic, also known as the "Early Stone Age" in Africa. Finally, this layer encompasses the three oldest specific embodiments or "industries" of stone technology. Those few stone tools known from 3 MYA are called ***Lomekwian***. The tools in use 2 MYA belong to the ***Oldowan*** Industry, and those from 1 MYA fall into the ***Acheulean*** Industry. Not all scientists agree that these classifications are meaningful, [1] but they are the preferred archaeological terms for now.

As in earlier chapters, planet Earth itself set the stage for its natural history. Climate and geography directed plant evolution, which affected animal life and human ancestry. For the last few million years, global climate has been characterized by a series of ice ages. Section II of this chapter discusses the overall causes and effects of these ice ages. For our purposes, the most important consequence was the evolution of what we now call the *Homo* genus – early humans. The paleontological and archaeological record of that evolution – the "hard" data of bones and stones – is the subject of Section III.

Chapter 7 was the point of departure for the hominin clade from the rest of the great apes. The commonalities of humans with other apes were discussed in Chapter 7. Chapter 6 focuses on the differences, which are harder to date but are reserved for this chapter as a practical matter. Aside from the skeletal anatomy, Section IV discusses the major soft-tissue and behavioral traits that set the hominins and humans apart from chimpanzees.

II. The Ice Ages

A. The Rule: Glacials

Chapter 7 introduced a long-term global cooling trend. Shortly after 3 million years ago, the climate crossed a critical threshold. The polar ice caps grew, extending well into the temperate zones. The Earth entered an ice age. This Quaternary ice age was not the first or the most severe. Geologists know of four earlier major ice ages. In our logarithmic history, though, the others were just blips in deep time. The Quaternary ice age completely dominates our study of the past few million years. Technically, we are still in it.

What causes the polar ice caps to grow? Chapter 7 discussed several long-term contributing factors related to plate tectonics, ocean currents, and the composition of the atmosphere. Once global conditions are right, there are two major proximate causes: one on land and another at sea.

Ice sheets on land are called ***glaciers***. A glacier is simply a perennial accumulation of snow. If more snow falls in the winter than melts the following summer, then that snow cover persists year-round. Next year, it grows a little larger. After many years, the deep layers harden into solid ice. As a glacier grows to massive scale, its sheer weight gives it a life of its own.

Glaciers can creep down slopes, carve fjords, displace boulders, calve ***icebergs*** into the ocean, and even deform the crust of the earth beneath them. Northern glaciers are mostly predisposed to form in Canada and the Rockies, Greenland, northern Europe, western Siberia, the Himalayas, and the Alps. In the southern hemisphere, they are almost entirely restricted to Antarctica but can also form in the southern Andes.

Meanwhile, the surface of the ocean can freeze over to form ***sea ice***. It takes protracted cold weather to do this, but it does not require any precipitation. Colder temperatures make sea ice deeper and more durable and enable it to persist at lower latitudes.

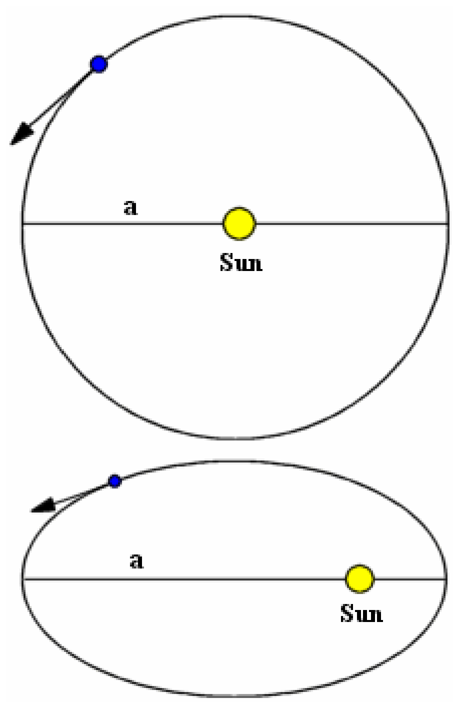
Ice sheets on land and sea alike feed themselves with a positive feedback loop. White ice reflects much more sunlight than the darker soil or water beneath it. As the icy Earth reflects more light and absorbs less, temperatures drop even further and enable the ice to encroach closer to the equator. At times, ocean waters have frozen fully down both coasts of Canada and around Europe as far south as the British Isles. Glaciers have reached lowlands as far south as 40º N, the latitude of the central United States. Sure, Nebraska gets snow every winter. But can you imagine visiting Nebraska in July and finding it covered with ice a mile thick? That's the difference between winter weather and an ice age.

An ice age has an enormous impact on life. A glacial ecosystem can support little more than microbes, moss, algae, worms, and some small birds. [2] Most native terrestrial life forms must surrender their habitats to the ice sheets. Sea ice supports a much richer food web (polar bears, walruses, penguins) but is less stable and covers a limited area. But the impact doesn't end at the ice's edge. Polar caps influence the rest of the world, even aside from temperature. An ice age results in a dry climate: the more water gets locked away in glaciers and sea ice, the less is available to recirculate into the atmosphere. Furthermore, glaciers lock up large amounts of water on land that would otherwise melt and find its way to the ocean. As a result, sea levels fall, sometimes changing the shapes of continental shorelines. Sea ice does not affect sea level, as you might notice when the ice in your drinking water melts and does not cause overflow.

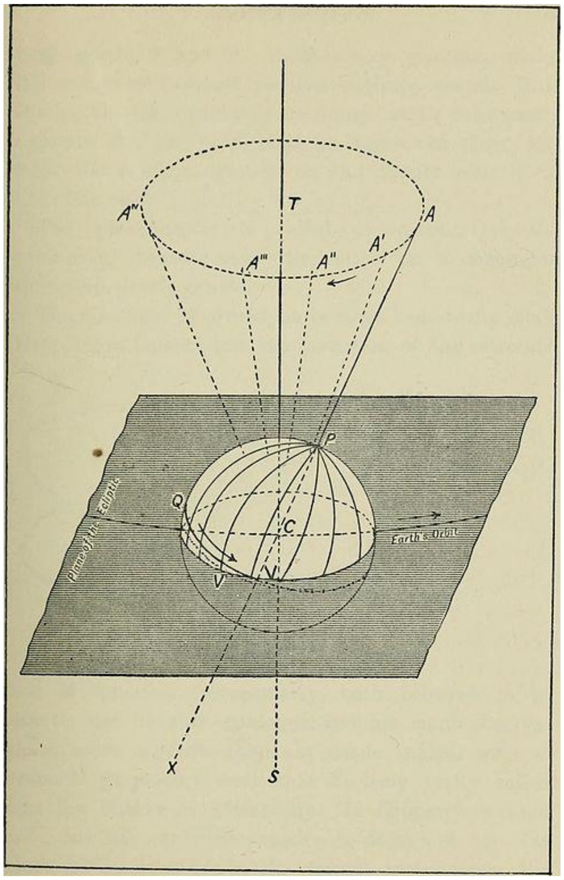
B. The Exception: Interglacials

As a rule, the planet has been in an ice age state for the last three million years. Fortunately for us, it is *barely* an ice age. When conditions conspire to produce particularly warm northern summers / southern winters, summertime melting exceeds winter freezing and the ice momentarily retreats back to its polar realms. As you might guess, we are lucky enough to be in one of those exceptional periods right now, an ***interglacial***. The pattern of the Quaternary has been 100,000-year glacial periods punctuated by 10,000-year interglacials. These climatic fluctuations are caused by complex planetary wobbles known as ***Milankovitch Cycles***, named after the amateur astronomer who spent three decades of his spare time calculating their effects by hand. In plain English, we might call them the shape of Earth's orbit, the angle of Earth's tilt, and the direction of Earth's tilt.

Earth's orbit, like every planet's, is an ellipse or a "stretched circle". ***Eccentricity*** describes the amount of stretch in the ellipse. Under the gravitational influence of Jupiter and Saturn, Earth's orbit fluctuates from minimum eccentricity to maximum and back to minimum again in 100,000-year cycles. When the orbit is at its most eccentric, the seasons are at their most extreme and the Earth's average distance to the sun is at a minimum. [3] These are prime conditions for glacial thaw. The glacial fluctuations of the past one million years closely match this 100,000-year period, but Earth's eccentric variation is very small and not enough by itself to account for interglacials. [4]



Exaggerated change in Earth's orbital eccentricity. An eccentric orbit brings Earth slightly closer to the sun on average, and more importantly it makes the seasons more extreme.



Precession of the equinoxes. Line A shows Earth's axis today. Lines A', A'' etc show the precession of the axis around a cone in a 25,000 year cycle, causing the seasons to shift around Earth's orbit.

Nothing in the solar system is perfectly symmetric or aligned. Earth has an equatorial bulge. [*] The planes of Earth's orbit, Earth's equator, and the moon's orbit are all slightly offset from one another. As a result of all these imbalances, the gravity of the moon and sun tug on Earth's orbital axis and slowly twist it around in a cone. This causes a 25,000-year cycle in stellar north, the direction in which Earth's North Pole points toward the stars. Sometimes the North Star is Vega, ¼ of the entire night sky away from Polaris! For purposes of climate change, the important issue is that northern summertime occurs when the North Pole faces the sun. The twisting axis causes summer to occur at varying points around Earth's orbit – sometimes when Earth is closer to the sun and sometimes when it's farther away. Astronomers call this seasonal effect the ***precession of the equinoxes***. When northern summertime occurs close to the sun, we get the unusually warm northern summers that promote interglacials. [5]

Due to the laws of physics, precession of the equinoxes causes yet another cycle, a precession of ***obliquity***. [6] Obliquity measures the angle at which Earth's axis (through the poles) is tilted from its orbital axis (perpendicular to its orbit around the sun). This angle makes a 41,000-year cycle from about 22º to 25º and back again. A steeper obliquity causes greater seasonal variations and more intense northern summers, so it is the higher obliquity that favors interglacial thaws. [7]

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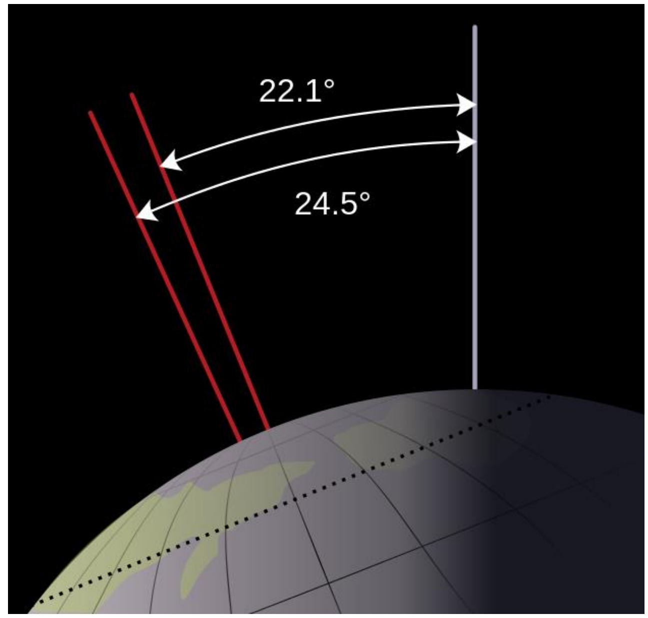
[*] Who doesn't?!



Obliquity. The tilt of Earth's axis (red) oscillates within this narrow range.

The latter two cycles do not affect the total *amount* of solar energy to reach Earth, but rather the *distribution* of that energy around the globe and throughout the year. That's how touchy the climate is! The patterns of sunlight make a difference because of Earth's own asymmetries. The Arctic and Antarctic zones are polar opposites in more ways than one. The North Pole is in the center of a small ocean surrounded by land. The South Pole is situated on a small continent surrounded by water. It is much harder to melt glaciers in the southern hemisphere, which has land at the most extreme latitudes. In fact, Antarctica has been permanently glaciated since Chapter 7. The Arctic Ocean has limited area to form sea ice, but when ice does form there it is landlocked and stable. While the Antarctic Ocean is nearly unlimited in size, the ice that forms there is unrestrained from drifting northward and melting. Another major difference between the poles is their snowfall. The Gulf Stream delivers copious precipitation to the Arctic Circle, while Antarctica is one of the most arid regions on Earth. That is fortunate, because if the South Pole got as much snow as the North, most of the world's fresh water supply would now be locked up in the southern polar cap! Early studies of the ice ages focused exclusively on the northern hemisphere because that was where the scientists lived and made their discoveries. More recent evidence suggests that southern sea ice has had particularly strong influence on the ice ages of the past million years. [8]

The Milankovitch Cycles are too complex to fully understand here. There are a few other cycles that Milankovitch did not know about. They all interact with each other, sometimes reinforcing and sometimes cancelling each other out. Sunlight further interacts with terrestrial conditions such as currents, atmosphere, geography, and even life. The takeaway point is that these past three million years have been 80 – 90% ice ages. The climate that we call "normal" today only occurs in exceptional times called interglacials. Interglacials tend to begin suddenly, last about 10,000 years, and then gradually succumb to 100,000 more years of ice. [9]

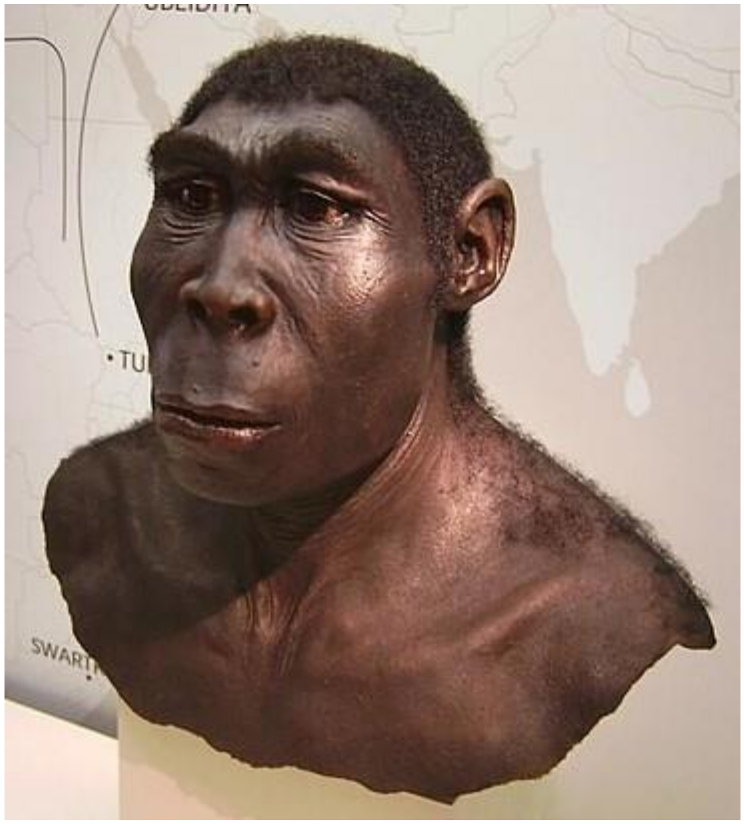
III. Early Humans

A. Genus *Homo*

As the ice ages began three million years ago, our ancestors were the hominins of eastern and southern Africa. They never saw glaciers or even much snow, but their environment was impacted by the cycle of wet and dry climate. Ice ages led to an arid Africa with increased grasslands and deserts at the expense of woods. It is surely no coincidence that in the early Quaternary hominins evolved a long striding gait and became fully terrestrial animals. Grasslands grew to their maximum range around 2 MYA. [10] At the same time and place, we first find fossils classified in genus *Homo*, the paleontological definition of "human".

We must always remember that the line between hominins and humans is fuzzy and arbitrary. That being said, of course we are naturally curious about the first beings that we would recognize as human. The earliest species to have been given this title is *Homo habilis*, which inhabited eastern Africa around 2 MYA. This is a benchmark transitory species, still with Australopithecine size and proportions, but with a larger braincase, more agile hands, and a command of tools. (*Habilis* means "handyman".) A facial feature that made *H. habilis* look more human was a reduction of the snout into a flatter mouth.

The star of this chapter is *Homo erectus*, "upright man". Dated conservatively to the interval of 1.8 – 0.3 MYA, this was the longest-living human species of all time. It was also the farthest-ranging of its day. *Homo erectus* was the species that took the bold new step where no hominin had gone before: out of Africa. [11] Its range eventually expanded to all of Africa, southern Europe, and southern Asia, all the way to China and Indonesia, where famous early discoveries were known as "Peking Man" and "Java Man". The strictly African version of *H. erectus* is called *H. ergaster*.



A* Homo ergaster / erectus *reconstruction. See endnote for attribution.

Homo erectus looked very similar to us in overall size and shape. [12] It was larger than earlier hominins and had a more modern proportion of shorter arms and longer legs. Its teeth and jaws were shrinking but still larger than ours. *Erectus* was the first species to sport the uniquely human nose. The projecting nasal bone was a relatively minor alteration of the skull, but it makes immense psychological difference to us when we look at a face and judge it as "human" or "animal". Like all apes before it, the *erectus* skull had a prominent bony brow ridge and essentially no forehead; the top of the head appeared "squashed flat" compared to ours. Below the neck, it had the same skeleton as us but with more robust bones.

The first humans found in Europe are given the name *Homo antecessor*. Fossils from Spain date to about 1 MYA. A slightly younger European species is *Homo heidelbergensis*, dated conservatively to 600 – 400 TYA and also found in Africa and southwest Asia. Heidelbergs exhibited some relatively sophisticated behavior such as building shelters and using spears. Humans of this period looked very similar to one another. It takes expertise to point out the subtle anatomical differences among these early *Homo* species.

Europe's famous Neanderthal man (officially *Homo neanderthalensis*) is known almost entirely from much younger fossils dating to the Chapter 5 time scale. However, DNA analysis recently identified some 430,000-year-old human remains in Spain as early Neanderthals. [13] The same study concluded that Neanderthals and modern humans diverged from a common ancestor around 600 – 800 TYA. [14] This leads to *H. antecessor* or *heidelbergensis* as good candidates for the Neanderthal / modern human common ancestor. Neanderthals eventually spread eastward to central Asia. They stuck to high latitudes, apparently thriving near the glacial line as they fed on cold-climate animals.

B. The Multiregional Hypothesis

One of the most fundamental debates about early human origins concerns long-term ancestry and migration. Early humans – humans that were not quite anatomically identical to us – roamed Africa, Asia, and Europe for two million years. By criteria of skeletal appearance, some scientists have categorized the fossil record into more than ten different human species. Now they are all gone but us *Homo sapiens*. Why is that?

Here we have to pick at the competing definitions of the word "species". We can define fossil species by physical features or by phylogenic relationships. Appearances are much easier to measure, but they don't tell the full story of ancestry. The real question is: how many fossil human "species" were evolutionary dead-ends, and how many belonged to the lineage that still lives on with us?

The two classic answers to this question are hypotheses called Multiregional Evolution (***MRE***) and Recent African Evolution (***RAE***). Both were refined in the 1980s. In light of evidence since then, they seem to be converging toward a middle ground. Still, contrasting their differences is a good way to frame the issue.

In its extreme form, the MRE hypothesis contends that *Homo* has always been one species, a widespread but continuous gene pool. [15] Early human species such as *ergaster*, *antecessor,* and *heidelbergensis* were just local variations of *Homo erectus*. The Old World supercontinent is vast, but it does not pose any distinct boundaries to human mating. Genes continued to flow from one end to the other, and *Homo sapiens* is the long-term result of this interbreeding across multiple regions. Local idiosyncrasies eventually got ironed out in the universal human. Under this hypothesis, human beings ourselves were the world's first product of globalization!

The RAE hypothesis (currently the majority opinion) [16] views the *Homo* genus as several species that did not mate with each other. *Homo sapiens* was just one of them. After evolving about 100,000 years ago in Africa, according to RAE, our species then rapidly populated the rest of the world and drove the rest of the human genus to extinction. Evidence in support of RAE will be taken up in Chapter 5.

The earliest known Asian humans, dated to 1.8 MYA, were discovered in Georgia in the 1990s – 2000s. [17] The few skeletons found there exhibited so much diversity that they might have been regarded as different species if they had been found in different locations. [18] This realization has prompted scientists to be more conservative about lumping physical variations together into single species. In other words, the number of early human species might be overestimated based on skeletal features alone.

MRE advocates believe in a "regional continuity" of fossil and cultural remains. In each particular region, human fossils bear a certain combination of traits that has never changed. For example, northern Chinese fossil skulls have particular "Chinese" features * that appeared the same 500,000 years ago as today. [19] These features were not wiped out by an African invasion. The same is true of tool use; Chinese early humans never adopted the African hand axe. [20] Furthermore, fossils in multiple regions exhibit a gradual long-term transition from *erectus* or Neanderthal features to *sapiens* features. [21]

The strongest evidence in favor of MRE is certain DNA analysis. One study showed an ongoing pattern of *gene flow* across the Old World for most of the last two million years. [22] Gene flow can occur when one group migrates and mates as it goes, or when communities mate in one gradual continuum across the continent. There was a mass migration several hundred thousand years ago, which included the travels of *Homo antecessor* / *heidelbergensis* from Africa into Europe and Asia. [23] This mass migration was characterized by assimilation of new genes into old populations. [24] It is now well known that Neanderthal DNA is not completely extinct, but comprises a small percentage of today's human genome. [25] Some African / European mating even seems to date back at least 200,000 years, which would be impossible if modern humans only left Africa 100 TYA. [26] These conclusions would seem to close the case on RAE, but MRE is imperfect [27] and of course we have only heard one side of the story. To be continued in Chapter 5 … .

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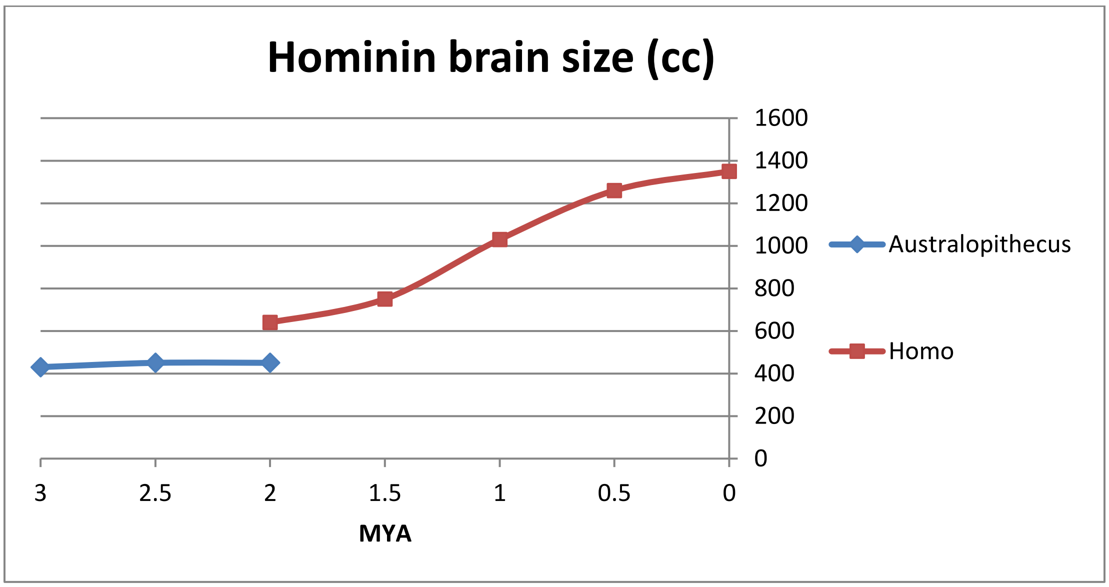
* Strictly skeletal features, not the outward skin / hair / eye appearances that we call "race" today.

C. The Big Brain Bang

One of the most striking features of the human fossil record is the ballooning brain. Brain size is limited by cranial capacity, the volume of the skull's hollow interior. *Australopithecus* species had an average cranial capacity of 450 cc, * slightly larger than a modern chimpanzee's, and their capacity held steady for two million years. In the two million years since, the *Homo* genus has tripled that volume! [28]



Average brain size for species spaced apart by 500,000 years

Sheer brain size is not a completely fair measurement, because humans have larger bodies than Australopithecines. Yet even when brain size is measured as a percentage of body mass, this ratio has roughly doubled in the same time frame. [29] The trend is undeniably cast in stone.

The big brain bang raises two obvious questions with not-so-obvious answers: the cause and the effect. The field abounds with hypotheses. Several factors that are commonly cited as causes are also described as effects. This seems sensible; a combination of positive feedback loops could have dramatic consequences. For example, the use of tools can facilitate butchering animals,

* This cc stands for "cubic centimeters", not "cranial capacity".

which in turn can feed a larger brain. If a larger brain is a smarter brain, then it can invent better tools for hunting and butchering … *ad infinitum*. [30] Likewise, if smarter early humans could outlive and outmate their dimwitted neighbors, they would have more egg headed children, initiating a cerebral arms race. [31]

The underlying assumption here, though, is that larger brains are smarter. This is true in a very gross sense (vertebrates are certainly more intelligent than insects) but, on closer comparison, the brain size / intelligence correlation is very weak, especially among individuals within a species. [32] Compounding this, early humans did not display many immediate signs of intellectual progress. Aside from tools and fire, most indications of humanity's remarkable intelligence occurred only within the Chapter 5 time frame. It seems that the brain may have enlarged for different reasons, secondarily acquiring an exceptional potential that was exploited later.

Could it have had something to do with climate? The synchronization of the big brain bang with the ice ages, and with humanity's expansions out of Africa, is too compelling to ignore. It was around two million years ago that *H. erectus* first encountered winter weather, during which plants were dormant and humans had to learn how to hunt to survive. Compared to the other apes, humans had by far the broadest range. Perhaps braininess was man's adaptation to becoming a generalist, able to conquer a variety of niches. Then there were the longer-term cycles of climate change. A species acclimated to harsh ice age weather could flourish explosively in a bountiful interglacial (such as the present one; see Chapter 4). These "boom times" could lead to faster growth and sexual maturity. Some scientists attribute our large head-to-body ratio as a consequence of juvenilization – the carry-over of childlike proportions into adulthood – especially during such times of rapid growth and reproduction. [33]

Now that we are endowed with our top-heavy anatomy, we think of it as an obvious blessing. We must remember that every evolutionary gain comes at a cost. Human brains are ridiculously expensive. We spend 20% of our energy on this 2% of our mass. [34] Worse yet, large brains and skulls make childbirth difficult, not an uncommon cause of death for mothers and infants. The solution has been a slowdown of body growth, yet this has resulted in human infants' being abnormally underdeveloped and helpless. The fact that humans became so brainy despite these serious challenges suggests that there must have been a persistent evolutionary pressure behind the trend.

The modern human brain is not anatomically outstanding by any single metric. [35] It is not the largest brain by absolute or relative size. It does not have the most neurons or the largest cortex. We seem to have gotten lucky with a double whammy: primate brain structure augmented by human brain size. Elephants and whales have larger brains, but primates evolved denser and faster neurons. [36] Then the big brain bang made human brains exceptionally large and complex [37] even for primates.

D. Tools

As discussed in the introduction, the field of archaeology – the study of human artifacts – dates back about three million years. For most of this time, the only artifacts to be found are those made of stone. Early humans may have made tools out of wood or bones, but most of them are long gone. [38] Metal working came much more recently, so the Stone Age is aptly named as the time when stone tools were at the "cutting edge" of technology. In fact, though today we use the phrase "Stone Age technology" as an insult, in its time it was revolutionary.

Chapter 7 introduced tool use as an outgrowth of apes' special mechanical insight. Chimpanzees commonly crack nuts open with hammer stones and use sticks to catch insects. Hominins probably had a similar toolkit, but they took it to another level when they began making their own stone tools. Chimpanzees (and presumably early hominins) use stones as they find them. Only humans [*] can modify stones to create new special-purpose tools. Functionally, human tools go beyond mere hammering and usually have sharp edges; we are the only animal to use tools for cutting and scraping.

There are multiple reasons that such tools came from humans alone, even aside from advanced intellect. The earliest tools would be especially valuable for butchery, a more urgent need for increasingly carnivorous humans than for their jungle cousins. The earliest evidence of tool usage takes the form of notches cut in animal bone, which bear the distinctive pattern of butchering blades. [39] We can imagine a group of men carving up an antelope carcass quickly before the lions and hyenas arrive, and proudly carrying the meat and leather back home for their family. Furthermore, human hands, with their long thumbs and fine musculature, have a much better

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[*] and a few individual apes specifically tutored by humans

precision grip than other apes. Domesticated apes are not very good at making humanesque tools even when they are taught.

It is not clear who the first tool-crafting hominins were. The record was once given to *Homo habilis,* which was actually defined as human on the basis of tools. However, the archaeological record has now been pushed back past three million years, well beyond *H. habilis*. Species such as *A. garhi* and *Kenyanthropus platyops* are now considered likely candidates for the earliest tool makers, making them "human" by at least one definition!

The basic technique of making stone tools is called ***knapping***. A knapper strikes one stone, the ***core***, with another stone, the hammer. When the core is properly selected and properly struck, the hammer will knock sharp *flakes* off of it. The best flakes are functional as scrapers and blades, and the core itself can serve as a larger tool. Knapping is an art much more sophisticated than just bashing rocks together. Selecting the wrong stones or striking them together improperly will result in useless shards. A modern hobbyist must spend years mastering the craft. [40] Clearly, our ancestors found tool-making important enough to devote arduous practice to it.

The Lomekwian tools from 3.3 MYA were large and crude by later standards, and have only been found in one location. By 2.5 MYA, tool use was widespread and moderately standardized. Oldowan or "pebble tool" technology used round pebble stones. [41] Tool makers recognized that certain minerals worked better than others, and they learned how to find smooth stones in riverbeds. The Oldowan technique is thus the first evidence of human culture; it seemed to involve a diffusion of knowledge. *Homo erectus* adopted Oldowan technology and took it out of Africa. Oldowan sites are found from Spain to Korea.

An Oldowan chopper.
See endnote for attribution.

It was also *H. erectus* who advanced tools to the Acheulean stage, which eventually spread almost everywhere except China. The icon of Acheulean technology is the *bifacial hand axe*, a core stone carefully carved into a hand-sized teardrop shape. [42] Hand axes are very symmetric and deliberately shaped. It is difficult for a layman to differentiate early Oldowan tools from naturally occurring rocks. Acheulean hand axes are very obviously man-made. Looking at one gives a glimpse into a mind with an undeniably human form of conscious agency, stunning for an artifact millions of years old.

An Acheulean hand axe. See endnote for attribution.

Tools confer enormous benefits for feeding and defense, so they had quite an impact on the evolution of their makers. As tools took over some functions of muscles and teeth, the entire body became more gracile. The unique attributes of the human hand show strong evidence of selection for grasping objects, throwing or hurling them together, and making precise manipulations – and this evolution happened quickly within the last two million years. [43] It seems that tools made man just as man made tools.

IV. The Origins Of Human Nature

Much of what makes us human derives from the fact that we are eukaryotes, animals, tetrapods, mammals, primates, and apes. But when we use the term "human nature", we are usually thinking of the qualities that set us apart from all other animals, even the other great apes. While the most dramatic behavior was manifested more recently, evolution was hard at work defining the human animal millions of years ago.

A. Meat, Hunting, and Cooking

You are what you eat. By that adage, our Pleistocene ancestors went through quite a transformation. Our diet is one of the sharp dividing lines between humans and other apes. The two major unique elements of our diet are meat and cooked food.

Chimps and humans are the only apes that eat vertebrate meat, and humans eat quite a bit more. Because we also eat a large amount of plant matter, we are classified as ***omnivores***. Eating meat allows us to obtain a large proportion of our calories from animal fat instead of plant oils and carbohydrates.

Most likely, hominins always ate some invertebrate meat (insects, snails, etc.) as all apes do. Australopithecines also ate seeds and nuts, so their digestive systems were already prepared for relatively concentrated doses of protein and lipids. Hominins probably next progressed to catching small vertebrates and scavenging large animal carcasses. Judging from cut marks on animal bones, they were already butchering cow-sized animals (presumptively scavenged carcasses) by 3 MYA. [44] As they relocated to sparser wintry environments, early humans had to rely even more on meat to supplement a dwindling fruit supply. By 2 MYA they were eating seafood, [45] which is often cited as an important factor for early human brain development. [46] For their grand finale, early humans took to hunting large game – boars, deer, cattle, hippos, all the way to elephants. This is a remarkable path to follow for a relatively small, slow creature with no claws or fangs. The earliest evidence of a human hunt dates to 2MYA. [47] It may have been another million years before hunting was common.

When it comes to early humans like *Homo erectus*, the only adventure that captures our imagination more than an elephant hunt is the domestication of fire. Humans learned how to preserve wildfire long before they mastered the art of creating their own. [48] The timing of these events is uncertain. It’s safe to say that some humans were definitely keeping fires, if not yet lighting them, by several hundred thousand years ago. [49]

Heating food *denatures* its macromolecules, breaking them up or “loosening” them so that it is easier for the body to digest them. Cooking also helps kill bacteria and preserve food. It is just as effective for plant matter as meat (can you imagine eating a raw yam?) so the quest for fire could have occurred independently of the hunt.

Meat and cooked food are "high quality" food dense in calories and minerals. On the flip side, they are difficult to obtain. Cooking and hunting take time and energy. Hunting is a high-risk / high-return gamble. [50] These were the choices that early humans made. High quality food changed the human body forever, to the extent that we now depend on it. Compared to the other apes, the human digestive system is small for our bodies. As a proportion of the gastrointestinal tract, humans have a large small intestine, which does the bulk of digestion for nourishment, and a small large intestine, which post-processes the lower-quality food. [51] According to the appealing "expensive tissue" hypothesis, [52] the availability of high quality food allowed hominins to downgrade the gut and re-invest that energy to the growing body and brain.

Omnivory, hunting, and cooking were as revolutionary for human behavior as for the body. Hunting-gathering or ***foraging*** was the predominant human lifestyle from the dawn of the genus until the Chapter 4 time frame. Family structure and gender relations, social cooperation and competition, and the role of the human species within the animal kingdom were all cast within the foraging framework. For example, male hunting / female gathering was the original human division of labor. The practice of sharing meat was the foundation of proto-politics, -insurance, and -economics for millions of years. [53] Perhaps due to our high-quality diets, [54] humans even reproduce much more rapidly than other apes. And as we all know, fire serves more purposes than cooking. Protected within the warm glow of their campfires, early humans became the dominant species of an ever-expanding habitat.

B. Naked Apes Running All Around

For his classic book describing humans from a zoologist's perspective, Desmond Morris chose the title *The Naked Ape*. Our bare skin is so anomalous that it is one of the first physical features we cite when we dignify ourselves as "non-animal". Truth be told, humans have just as many body hairs as other apes; it's just that ours are much shorter and finer. [55] Without splitting hairs, though, the fact remains that humans made a dramatic makeover. This inquiry into the origins of hairlessness will lead us into a surprising and sometimes speculative web of highlights in the making of the human animal.

Besides hairlessness, human skin has another important property: humans sweat profusely and more efficiently than any other animal. When human sweat evaporates, it very effectively carries heat away from the body – but only when it evaporates directly from the surface of the skin, not an outer layer of fur. Therefore, it's likely that sweating and bare skin evolved together to help keep early humans cool, even as they were active in the daytime. [56] Incidentally, when bare skin is exposed to intense sun, it must darken to protect the body from excess ultra-violet sunlight. The first bare-skinned humans almost surely had very dark complexions, as tropical populations still do today.

There is some irony to the fact that the human body perfected heat venting as the planet plunged into ice ages. Humans could have used fur coats over the next million years as they migrated into northern climes, but the hair loss probably occurred earlier while they were still restricted to tropical and sub-tropical regions. In fact, ice ages led to a more arid Africa with fewer shade trees, thus exacerbating humans' exposure to sun.

Besides that, sunlight is not the only source of heat. The body produces heat of its own; hairlessness and sweat glands are indicative of an animal that burns a great deal of energy. We already know of one particularly energy-hungry organ – the human brain. Our bare skin might be just the radiator required to keep the engine in our head from overheating.

Many scientists believe that early humans also generated a great deal of body heat by running. [57] Not until the human genus did hominins fully commit themselves to life out of the trees and down on the ground. While Australopithecines did certainly walk upright, it was probably a slow waddle of a walk. *Homo erectus* gave bipedalism a whole new swagger, the steady long-legged stride that we use today. In fact, from *erectus* we have inherited a body that appears engineered for endurance running.

Kinesiologists will tell you that running is not simply fast walking, and you understand this instinctively when you walk with increasing speed until your body must "shift gears" into a run. Running takes the joints and muscles through a greater range of motions, including a small vertical leap with each stride, and it places all the weight on one foot. It places great stress on bones, muscles, and ligaments, and it requires better subconscious balance and control than walking. Running long distances is especially demanding of the digestive and cardiovascular systems. From the shape of the heel to the size of the butt, the human body has adapted to meet all of these demands and more. [58] What we lack in speed, we make up for in endurance. In a marathon, the slow-and-steady human can outrun the best sprinters, including antelopes [59] and cheetahs. [60]

Humans are so good at endurance running that it makes us suspect there was a compelling reason for it. Why were all those naked apes running around so much two million years ago? Today's scientists debate whether running was necessary to scavenge or hunt. Maybe early humans had to routinely outrace competing scavengers or even chase prey to exhaustion. [61] It's just as plausible that running helped humans evade predators. Naked apes were curiously vulnerable creatures out in the open. They were not especially large or strong, and they lacked armor. Their stone tools were probably not very effective as weapons. [62] Perhaps they got by on being swift of mind and fleet of foot.

C. Family and Social Life

To us, the institutions of marriage and nuclear family seem so natural that we never stop to question them. But when it comes to sex and parenting, humans are actually the freaks of nature. We are the only social mammal to pair up in long-term bonds. Fathers commit an exceptional amount of time, energy, and resources to supporting their own children. Paternal care is unknown to other social mammals. It makes sense for humans because fathers (usually) know who their own children are. We are not an entirely monogamous species and probably never were, but the roles of "husband" and "father" are institutionalized in nearly all human societies. [63]

The aspects of human sexuality and parenting that differ from other apes' are those that evolved in response to specific human needs. Therefore, we should not be surprised to find them related to other uniquely human conditions. In fact, scientists are currently attempting to explain these sexual behaviors in their relation to temperate climate, hunting, cooking, large brains, and even tools. This is a tantalizing and frustrating field. The origin of human family and social life is a big question for which we crave definite answers, but it remains a mystery open to speculation. The best we can do here is summarize some of the most reasonable and favored hypotheses.

As children's brains (and skulls) grew, they were forced into slower development so that they were not too large at birth. [64] Consequently, human infants are absolutely helpless for years. Following childbirth, nursing puts mothers in a very vulnerable position as well. Two years of breastfeeding is even more demanding on a mother's body than nine months of pregnancy. Mother and her child must be well fed, exactly at the time when her foraging capabilities are at a low. [65] A caretaking father can help provide food and protection for the family unit.

In a social setting, the success of childhood is measured not only by nutrition but also by education. As humans lived in increasingly complex bands of smarter peers, childhood became a foundational period to learn complex skills (such as knapping tools) and social competence. As humans usually live in male-based kin groups – women traditionally leave home at maturity and apparently have done so for millions of years [66] – the paternal connection is especially important.

From the male point of view, the commitment to fatherhood required (or followed) a transition from promiscuity. To oversimplify the issue, a male can spend his time and effort either raising his children at home or leaving a trail of love children with multiple single mothers. If it were up to his genes, he might opt for the latter. However, this is not entirely his choice to make. He is up against competitive males and cautious females. Monogamy is a social decision, not an individual one. One major benefit is more widespread availability of mates to all males, not just the dominant ones, without the need to fight. Humans are the least sexually dimorphic great ape. Men have relatively small bodies and small teeth, traits that generally indicate minimal male fighting. Human females have also swayed the communal decision by becoming more inclined to monogamy than promiscuous chimps or harem gorillas. [67]

Most mammalian females are receptive to mating only when they are "in heat", which usually coincides with ovulation and the opportunity for fertilization. Chimpanzee females blatantly signal their heat with swollen red genitals. Humans have gone to the opposite extreme, with an ovulation cycle that is concealed from men and even from women themselves. [68] Women no longer have a "heat" cycle, yet they are potentially receptive to their mates' advances at any time of month. We have replaced low-frequency / high-fertilization sex with a higher-frequency / lower-fertilization strategy. This gives sex a new non-reproductive role of pair-bonding and enticing the male to remain loyal. Humans are unique among social mammals for having sex in private. This intensifies the pair-bond as distinct from normal social relations. [69] Neurotransmitters such as AVP may play a role in emotionally bonding men to their mates and children. [70]

However it happened, the nuclear family – two parents and their biological children – has become the fundamental social unit in most human societies. Brothers and male cousins generally stay together and create extended family units. For most of the past few million years, the foraging lifestyle did not support large or stable communities. Family units fragmented into different ***bands***, though adjacent bands were connected by "marriage" and alliances. Humans have much better facial recognition than chimps and can recognize their relatives through the years, helping keep the peace between bands that exchanged brides. [71] On the flipside, bands also competed aggressively and violently for scarce resources. Family cohesion was essential for the ongoing cycle of cooperating with "us" to compete against "them". Human social life is the most complex of any animal, and our brains devote a large share of their powers to understanding each other.

D. Vocalization

The development of speech is one of the most inscrutable mysteries of human nature. It was once so open to guesswork that prestigious journals banned articles on the subject! There is now a growing field of indirect evidence from fossil anatomy, comparative linguistics, and prehistoric culture. To get a handle on it, I will separate speech into two aspects. ***Vocalization*** is the physical production of sound with the body. ***Language*** is the use of symbols to communicate meaning. These are two different concepts that just happen to intersect in human speech. The present discussion is limited to human vocalization, which, even without language, is fascinating in its own right. The linguistic aspect of speech will follow as one of the major topics of Chapter 5.

We generate speech with our ***larynx*** or "voice box". Exhaled air vibrates the vocal cords in the larynx. The sound produced by these cords is then amplified and modified in the mouth, nose, and throat. In these regards, humans are far from unique. All mammals and even reptiles have vocal cords. But a few features of human vocalization are truly unusual.

All non-human apes vocalize with air sacs, which are good amplifiers but would make speech sound somewhat muddled. [72] Humans lost air sacs somewhere along the way, trading them in for the ***pharynx***, a resonant tube in the upper throat. The pharynx was formed as the larynx descended below the base of the tongue.

The pharynx opened up space for the tongue to become more flexible. This in turn was critical, because only humans use the tongue and lips to shape sounds emerging from the mouth. Each letter of the alphabet owes its sound to the positioning of soft tissue. [73] Dozens of tiny muscles perform specialized functions such as opening / closing the jaw and lips, shaping the tongue, and controlling tension on the vocal cords. The human brain coordinates these movements precisely and rapidly; an average person pronounces about 10 sounds per second.

Human vocalization also relies heavily on breath control. When you speak a sentence, you start with a quick inhalation. Then you carefully pace your exhalation to support your voice evenly from beginning to end. Other apes lack control over their breath tempo, while humans have taken it to the extremes of inflection, poetry, and song.

The details of how, when, and "why" these features all evolved are unresolved. Some scientists claim that the first signs of culture, such as tools and fire, are evidence that *Homo erectus* had language 2 MYA. [74] On the other extreme, some believe that speech was not possible until the human throat acquired its modern proportions 50 TYA. [75] Some of the earliest fossil evidence of the transition is found in *H. heidelbergensis* about 600 TYA. Heidelberg Man is the first human known to have lost air sacs [76], and his ear anatomy was attuned to the frequencies of the human voice. [77] The nerve for controlling breath and speech apparatus is larger in Neanderthals and *H. sapiens* than in *erectus*, [78] implying that this enhancement also originated with Heidelberg.

These vocal features may have evolved along with language [79] or separately to serve different functions. For instance, an elongated pharynx amplifies and deepens vocal calls and makes a male sound artificially large, an advantage in social competition. [80] Interestingly, breath control is sometimes cited as a critical factor in the evolution of running. [81] In any event, when humans had the capacity to invent language, they needed means to communicate it with. It is hard to imagine a better medium than their incredible voices to convey such precision and emotion all at once.

V. Conclusions

An apt name for this chapter would be "The Human Animal". By and large, the first humans were just another animal, not a breed apart. Yet, like any animal, early *Homo* evolved a set of characteristics not shared by any other genus, including our closest ape cousins. Humans are as biologically unique as zebras or termites. Our large brain, bare skin, and agile tongue are just a few standout features.

Some of the most buzzworthy and controversial questions about evolution involve the characterization of human nature. What kind of diet are we "meant" to eat? Is it "natural" for humans to be monogamous? To search for answers, it is common to look to the early Pleistocene Epoch, when we (arbitrarily) seem to first recognize our ancestors as human. Although any conclusion based on the Pleistocene alone would be a pat answer, it can be insightful to review the environments in which some human behaviors were derived.

The human animal is a generalist. Originally shaped by the hot, dry plains of southeastern Africa, early human species colonized diverse ecosystems across all of Africa and southern Eurasia. The climate swings of the Quaternary ice ages further varied the landscapes that they encountered. Humans adapted by becoming intelligent and omnivorous. They learned to hunt, process, and cook food. Contrary to the paleo-diet fad, the human digestive and immune systems are now reliant on high quality meat and / or cooked food.

Late hominins or early humans underwent major changes in life history. Infants were born more helpless, childhood grew longer, females stopped signaling ovulation and became more monogamous, and males competed less with each other and bonded more with their mates and children. These trends all apparently contributed to formation of the nuclear family. Humans are highly social, though for millions of years their communities were no larger than loosely affiliated bands of extended families. Thus, what we think of as traditional marriage is suited specifically for that sparsely populated foraging environment (and for people with short lifespans). Variations on the theme might be just as “natural” in different settings.

Early humans were the smartest animal, yet they were still underdeveloped as intellectual beings. It is tantalizing to imagine what drove the big brain bang. The most popular hypotheses propose that braininess was forced by social competition and / or the creation of tools. Alternatively, it may have been a biological byproduct of juvenilization, a developmental carryover of childlike features (like large heads) into adulthood.

The first inklings that humans had mental powers beyond the other animals were stone tools, dating back to hominins 3MYA, and the use of fire, especially within the last million years. Otherwise, species like *Homo erectus* probably did not exhibit much of the spark that we now call human spirit. Its full realization would have to wait until the appearance of *Homo sapiens* in Chapter 5.

VI. Citations

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[1] John Shea, *Stone Tools in Human Evolution*, Cambridge University Press (2017).
[2] Arwyn Edwards, "Glacier ecosystems" (3/03/2014), http://www.antarcticglaciers.org/modern-glaciers/glacier-ecosystems/ (accessed and saved 1/21/2018).
[3] Chris Colose, "Milankovitch Cycles", *Skeptical Science* (7/22/2011), https://www.skepticalscience.com/Milankovitch.html (accessed and saved 2/3/2018).
[4] Eccentricity image by RJHall, CC-BY-SA-2.0 license, https://commons.wikimedia.org/wiki/File:Kepler3.gif (accessed and saved 2/03/18).
[5] Precession image by Internet Archive Book Images [No restrictions], via Wikimedia Commons, https://commons.wikimedia.org/wiki/File%3ADante_and_the_early_astronomers_(1913)_(14760606356).jpg (accessed 2/3/2018).
[6] Guy Worthey, "Astronomy: precession of earth", Washington State University (9/12/2000), http://astro.wsu.edu/worthey/astro/html/lec-precession.html (accessed and saved 2/03/18).
[7] Obliquity image by Robert Simmon, NASA GSFC, in the public domain as the work of a US government agency, https://earthobservatory.nasa.gov/Features/Milankovitch/ (accessed 2/03/2018).
[8] Jung-Eun Lee et al., "Hemispheric sea ice distribution sets the glacial tempo", *Geophysical Research Letters* vol. 44 # 2 (1/27/2017) 1008-1014, http://onlinelibrary.wiley.com/doi/10.1002/2016GL071307/full (paysite) (accessed and saved 1/28/2018). Summary by Kevin Stacey, "Earth's orbital variations and sea ice synch glacial periods" (1/26/2017), https://m.phys.org/news/2017-01-earth-orbital-variations-sea-ice.html (accessed and saved 1/28/2018).
[9] National Oceanic and Atmospheric Administration, "Glacial-Interglacial Cycles", https://www.ncdc.noaa.gov/abrupt-climate-change/Glacial-Interglacial%20Cycles (accessed and saved 1/28/2018).
[10] Thure E. Cerling et al., "Woody cover and hominin environments in the past 6 million years", *Nature* vol. 476 (8/4/2011) 51-56 at 55, http://www.nature.com/articles/nature10306 (accessed and saved 2/11/2018).
[11] Reid Ferring et al., "Earliest human occupations at Dmanisi (Georgian Caucasus) dated to 1.85-1.78 Ma", *PNAS* vol. 108 no. 26 (6/28/2011) 10432-10436, http://www.pnas.org/content/108/26/10432 (accessed and saved 2/18/2018).
[12] *Homo erectus* photograph: By User:Lillyundfreya [GFDL (http://www.gnu.org/copyleft/fdl.html), CC-BY-SA-3.0 (http://creativecommons.org/licenses/by-sa/3.0/)], https://commons.wikimedia.org/wiki/File%3AHomo_erectus.JPG (accessed and saved 3/25/18). Model at Westfälisches Museum für Archäologie, Herne, Germany; sculptor unknown.
[13] Matthias Meyer et al., "Nuclear DNA sequences from the Middle Pleistocene *Sima de los Huesos* hominins", *Nature* 531, 504-507 (3/24/2016), www.nature.com/articles/nature17405 (pay site; cover page accessed and saved 2/18/2018).
[14] Meyer 2016, as summarized by Ewen Callaway, "Oldest ancient-human DNA details dawn of Neanderthals", *Nature* 531, 286 (3/17/2016), https://www.nature.com/news/oldest-ancient-human-dna-details-dawn-of-neanderthals-1.19557 (accessed and saved 2/18/2018).
[15] Milford Wolpoff, Wu Zhi, and Alan Thorne, "Modern *Homo sapiens* Origins: A General Theory of Hominid Evolution Involving the Fossil Evidence from East Asia", in Fred Smith and Frank Spencer, editors, *The Origins of Modern Humans: A World Survey of the Fossil Evidence*, Liss publishers (New York, 1984) pp. 411 – 483. https://www.scribd.com/doc/56574117 (accessed and saved 2/25/2018; sign-up required).
[16] David Begun, "The Past, Present and Future of Palaeoanthropology". In: David Begun, editor, *A Companion to Paleoanthropology*. Wiley-Blackwell. (2013) p. 8. https://books.google.com/books?id=oIoT1RcFeCwC (accessed and relevant quote saved 2/25/2018).
[17] Abesalom Vekua, David Lordkipanidze, et al., "A new skull of early *Homo* from Dmanisi, Georgia", *Science* 297(5578) (7/05/2002), 85-9. https://www.ncbi.nlm.nih.gov/pubmed/12098694 (accessed and saved 2/25/2018).
[18] David Lordkipanidze (discoverer) quoted by Ian Sample in "Skull of Homo erectus throws story of human evolution into disarray", *The Guardian* (10/17/2013), https://www.theguardian.com/science/2013/oct/17/skull-homo-erectus-human-evolution (accessed and saved 2/25/2018).
[19] Milford Wolpoff, Wu Zhi, and Alan Thorne, "Modern *Homo sapiens* Origins: A General Theory of Hominid Evolution Involving the Fossil Evidence from East Asia", in Fred Smith and Frank Spencer, editors, *The Origins of*

Modern Humans: A World Survey of the Fossil Evidence, Liss publishers (New York, 1984) pp. 411 – 483. https://www.scribd.com/doc/56574117 (accessed and saved 2/25/2018; sign-up required

[20] Milford Wolpoff and Alan Thorne, "The multiregional evolution of humans", *Scientific American* vol. 13 no. 2s pp. 46 – 53 (May, 2003), http://www-personal.umich.edu/~wolpoff/Papers/Sci%20Am%202003.pdf (accessed and saved 3/03/2018).

[21] Berhane Asfaw et al., "Remains of *Homo erectus* from Bouri, Middle Awash, Ethiopia", *Nature* 416, 317-320 (3/21/2002), http://www.nature.com/articles/416317a (accessed and saved 3/03/2018).

[22] Alan Templeton, "Haplotype Trees and Modern Human Origins", Yearbook of Physical Anthropology 48:33-59 (2005). Stable URL https://www.ncbi.nlm.nih.gov/pubmed/16369961, free copy at http://esa.ipb.pt/pdf/28.pdf (accessed and saved 2/25/2018).

[23] Colin Groves, "Hominin migrations before *Homo sapiens*: Out of Africa – how many times?" in Peter Bellwood, editor, *The Global Prehistory of Human Migration*, Wiley (2015), pp. 21 – 23, https://books.google.com/books?id=TyJlBAAAQBAJ (accessed 2/25/2018).

[24] Alan R. Templeton, "Out of Africa again and again', *Nature* 416, 45-51 (3/07/2002), www.nature.com/articles/416045a (accessed and saved 2/24/2018).

[25] Richard E. Green et al., "A Draft Sequence of the Neandertal Genome", *Science* 328(5979): 710-722 (5/07/2010), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5100745/ (accessed and saved 3/10/2018).

[26] Cosimo Posth et al., "Deeply divergent archaic mitochondrial genome provides lower time boundary for African gene flow into Neanderthals", *Nature Communications* 8:16046 (7/04/2017), http://www.nature.com/articles/ncomms16046 (accessed and saved 3/25/2018). Plain English summary by Ann Gibbons, "Neandertals and modern humans started mating early", *Science* (7/04/2017), http://www.sciencemag.org/news/2017/07/neandertals-and-modern-humans-started-mating-early (accessed and saved 2/25/2018).

[27] Fred H. Smith, Anthony B. Falsetti, and Steven M. Donnelly, "Modern Human Origins", *Yearbook of Physical Anthropology* 32:35-68 (1989), http://onlinelibrary.wiley.com/doi/10.1002/ajpa.1330320504/epdf (accessed and saved 3/03/2018).

[28] Graph: Most data points taken from *The Human Past*, edited by Chris Scarre, Thames & Hudson (London, 2005), pp.62 – 65 and 90 – 91.

[29] I based this calculation on a CC of 450 cc for *A. afarensis* and 1,350 cc for *H. sapiens*, and a male-female average mass of 36 kg for *A. afarensis* and 63 kg for properweight *H. sapiens*.

[30] Kwang Hyun Ko, "Origins of human intelligence: The chain of tool-making and brain evolution", Anthropological Notebooks 22 (1):5-22 (2016), http://www.drustvo-antropologov.si/AN/PDF/2016_1/Anthropological_Notebooks_XXII_1_Ko.pdf (accessed and saved 3/18/2018).

[31] The "social intelligence hypothesis" grew out of Alison Jolly's research on primates in general. "Lemur Social Behavior and Primate Intelligence", *Science* vol. 153, Issue 3735, pp. 501-506 (July, 1966), http://science.sciencemag.org/content/153/3735/501 (accessed and saved 3/18/2018).

[32] Javier DeFelipe, "The evolution of the brain, the human nature of cortical circuits, and intellectual creativity", *Frontiers in Neuroanatomy*, vol. 5 Article 29 (May, 2011), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3098448/ (accessed and saved 3/18/2018).

[33] William H. Calvin, *The Ascent of Mind*, iUniverse.com publishers (Lincoln, NE, 2000), especially Chapter 3.

[34] Donald Clarke and Louis Sokoloff, "Circulation and energy metabolism in the brain", *Basic Neurochemistry: Molecular, Cellular and Medical Aspects*, 6th ed., G.J. Siegel editor, Lippincott-Raven Publishers (Philadelphia, 1999) 637 at 650-651, https://fordham.bepress.com/cgi/viewcontent.cgi?article=1082&context=chem_facultypubs (accessed and saved 3/18/2018).

[35] Suzana Herculano-Houzel, "The Remarkable, Yet Not Extraordinary, Human Brain as a Scaled-Up Primate Brain and Its Associated Cost", *In the Light of Evolution Volume VI: Brain and Behavior*, National Academies Press (Washington, DC, 1/25/2013) Ch. 8, https://www.ncbi.nlm.nih.gov/books/NBK207181/ (accessed and saved 3/11/2018).

[36] Gerhard Roth and Ursula Dicke, "Evolution of the brain and intelligence", *Trends in Cognitive Sciences* vol. 9 no. 5 (May, 2005), https://www.ncbi.nlm.nih.gov/pubmed/15866152 (accessed and saved 3/10/2018).

[37] Mark V. Flinn, "Evolutionary Anthropology of the Human Family", Ch. 2 of *The Oxford Handbook of Evolutionary Family Psychology*, Todd K. Shackelford and Catherine A. Salmon, ed., Oxford University Press

(New York, 2011), 12 – 32. On p. 13, Flinn enumerates ways in which the human brain has grown more complex as well as large.

[38] For example, see J. Lesnik and J.F. Thackeray, "The efficiency of stone and bone tools for opening termite mounds: implications for hominid tool use at Swartrkrans", *South African Journal of Science* 103 (Sep – Oct 2007), 354-356, http://www.scielo.org.za/scielo.php?script=sci_arttext&pid=S0038-23532007000500002 (accessed and saved 3/25/18).

[39] Shannon McPherron et al., "Evidence for stone-tool-assisted consumption of animal tissues before 3.39 million years ago at Dikika, Ethiopia", *Nature* 466, 857-860 (8/12/2010), http://www.nature.com/articles/nature09248 (accessed and saved 3/25/18).

[40] Deborah Olausson, "The Use and Abuse of Experimental Flintknapping in Archaeology", in H. Nami (ed) *Experiments and Interpretation of Traditional Technologies: Essays in Honor of Errett Callahan* (Lund University, 1/1/2010) pp. 37-56 at 37-38, http://portal.research.lu.se/ws/files/5536991/2425795.pdf (accessed and saved 3/24/18). Corroborated by personal correspondence with expert knapper Thomas Schorr-kon (2018), https://www.youtube.com/watch?v=FA2SNM9ueP4&lc=z22agn2arxfhxphjo04t1aokgrnbbemkvxvutexixv5mrk0h00410.1525729724968289

[41] Photograph of Oldowan tool: By José-Manuel Benito Álvarez (España) —> Locutus Borg (Own work) [Public domain], via Wikimedia Commons, https://commons.wikimedia.org/wiki/File%3ACanto_tallado_2-Guelmim-Es_Semara.jpg (accessed and saved 3/25/18).

[42] Photograph of Acheulean hand axe: By José-Manuel Benito Álvarez (España) —> Locutus Borg (Own work) [Public domain], via Wikimedia Commons, https://commons.wikimedia.org/wiki/File%3ABifaz_de_Atapuerca_(TG10).jpg (accessed and saved 3/25/18).

[43] Carol Ward et al., "Early Pleistocene third metacarpal from Kenya and the evolution of modern human-like hand morphology", *PNAS* vol 111 no 1 (1/07/2014), 121-124, http://www.pnas.org/content/111/1/121 (accessed and saved 3/25/18).

[44] Shannon McPherron et al., "Evidence for Stone-Tool-Assisted Consumption of Animal Tissues before 3.39 million years ago at Dikika, Ethiopia", *Nature* 466 (8/12/2010) 857-860, https://www.nature.com/articles/nature09248 (accessed and saved 4/15/18).

[45] David R. Braun et al., "Early hominin diet included diverse terrestrial and aquatic animals 1.95 Ma in East Turkana, Kenya", *PNAS* 107(22) (6/01/2010), 10002-10007, www.pnas.org/content/107/22/10002 (accessed and saved 4/15/18).

[46] Joanne Bradbury, "Docosahexaenoic Acid (DHA): An Ancient Nutrient for the Modern Human Brain", *Nutrients* 3(5) (May, 2011) 529-554, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3257695/#B1-nutrients-03-00529 (accessed and saved 4/15/18).

[47] Henry Bunn and Alia Gurtov, "Prey mortality profiles indicate that Early Pleistocene Homo at Olduvai was an ambush predator", *Quaternary International* 322-323 (2014) 44-53, http://www.olduvaiproject.org/wp-content/uploads/4-Bunn-Gurtov-hunting.pdf (accessed and saved 4/15/18).

[48] J.A.J. Gowlett, "The discovery of fire by humans: a long and convoluted process", *Phil. Trans. R. Soc. B* 371:20150164 (2016), http://rstb.royalsocietypublishing.org/content/371/1696/20150164 (accessed and saved 4/15/18).

[49] Francesco Berna et al., "Microstratigraphic evidence of *in situ* fire in the Acheulean strata of Wonderwerk Cave, Northern Cape province, South Africa", *PNAS* 109(20) (5/15/2012), E1215-E1220, https://doi.org/10.1073/pnas.1117620109 (accessed and saved 4/15/18).

[50] Kristen Hawkes, James O'Connell, and Nicholas Jones, "Hunting and Nuclear Families", *Current Anthropology* 42(5) (Dec., 2001), https://www.journals.uchicago.edu/doi/10.1086/322559 (accessed and saved 4/15/18).

[51] David J. Chivers and Claude Marcel Hladik, "Morphology of the gastrointestinal tract in primates: Comparisons with other mammals in relation to diet", *Journal of Morphology* 166(3) (December, 1980), 337-86, https://www.ncbi.nlm.nih.gov/pubmed/7441763 (accessed and saved 4/15/18).

[52] Leslie C. Aiello and Peter Wheeler, "The Expensive-Tissue Hypothesis: The Brain and the Digestive System in Human and Primate Evolution", *Current Anthropology* 36(2) (April, 1995), 199-221, https://www.journals.uchicago.edu/doi/10.1086/204350 (accessed 4/15/18).

[53] Craig B. Stanford, *The Hunting Apes: Meat Eating and the Origins of Human Behavior*, Princeton University Press (Princeton, 1999).

[54] Elia Psouni, Axel Janke, and Martin Garwicz, "Impact of Carnivory on Human Development and Evolution Revealed by a New Unifying Model of Weaning in Mammals", *PLoS ONE* 7(4): e32452, http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0032452 (accessed and saved 4/15/18).
[55] Nina G. Jablonski, *Skin: A Natural History*, University of California Press (2013), Kindle e-book edition location 531
[56] David R. Carrier, "The Energetic Paradox of Human Running and Hominid Evolution", *Current Anthropology* vol. 25, no. 4 (Aug – Oct 1984) 483 – 495, https://www.journals.uchicago.edu/doi/10.1086/203165 (accessed and saved 4/22/18).
[57] Carrier, ibid., and related literature.
[58] Dennis M. Bramble and Daniel E. Lieberman, "Endurance running and the evolution of Homo", Nature vol. 432 (11/18/2004), pp. 345-352, http://www.nature.com/articles/nature03052 (accessed and saved 4/22/18).
[59] David Attenborough, The Life of Mammals: Programme 10, Food For Thought (video documentary), BBCi, 2002, 30:00 – 37:00, https://www.bbc.co.uk/programmes/p009lwhq (accessed 5/06/18).
[60] BBC News, "Kenyans chase down and catch goat-killing cheetahs" (11/15/2013) www.bbc.com/news/world-africa-24953910 (accessed and saved 5/06/18).
[61] Travis Rayne Pickering and Henry T. Bunn, "The endurance running hypothesis and hunting and scavenging in savanna-woodlands", *Journal of Human Evolution* 53 (2007) 434-438, https://www.sciencedirect.com/science/article/pii/S0047248407001327?via%3Dihub (accessed and saved 4/22/18).
[62] John J. Shea, "Lithic Archaeology, or, What Stone Tools Can (and Can't) Tell Us about Early Hominin Diets", In Peter Ungar (Ed.) *Evolution of the Human Diet: The Known, the Unknown and the Unknowable*, pp. 212-229. Oxford, UK: Oxford University Press. https://www.academia.edu/3291695 (accessed and saved 5/06/18).
[63] George Peter Murdock, *Social Structure*, The MacMillan Company (New York, 1949), https://archive.org/details/socialstructure00murd (accessed 5/27/18).
[64] Mark V. Flinn, "Evolutionary Anthropology of the Human Family", Ch. 2 of *The Oxford Handbook of Evolutionary Family Psychology*, Todd K. Shackelford and Catherine A. Salmon, ed., Oxford University Press (New York, 2011), p. 19.
[65] Robert J. Quinlan, "Human Pair-Bonds: Evolutionary Functions, Ecological Variation, and Adaptive Development", *Evolutionary Anthropology* 17:227-238 (2008).
[66] Sandi R. Copeland et al., "Strontium isotope evidence for landscape use by early hominins", *Nature* 474, 76-78 (6/02/2011), https://www.nature.com/articles/nature10149 (accessed and saved 6/30/18).
[67] Sergey Gavrilets, "Human origins and the transition from promiscuity to pair-bonding", *PNAS* vol. 109 no. 25 (6/19/2012), 9923-9928, http://www.pnas.org/content/109/25/9923 (accessed and saved 5/13/18).
[68] Richard D. Alexander, "How Did Humans Evolve? Reflections on the Uniquely Unique Species", Special Publication No. 1, University of Michigan Museum of Zoology (1990), https://deepblue.lib.umich.edu/handle/2027.42/57178 (accessed and saved 5/12/18).
[69] Jared Diamond, *The Third Chimpanzee*, Harper Collins (New York, 2006) pp. 83 – 84.
[70] Anne E. Storey and Toni E. Ziegler, "Primate paternal care: interactions between biology and social experience", Horm Behav. 77:260-271 (January, 2016), https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4968077/pdf/nihms804454.pdf (accessed and saved 6/02/18).
[71] Flinn, op. cit., p. 16.
[72] Tobias Riede et al., "Mammalian laryngeal air sacs add variability to the vocal tract impedance: Physical and computational modeling", *J Acoustic Soc Am*. 124(1), 634-47 (July, 2008), https://www.ncbi.nlm.nih.gov/pubmed/18647005 (free PDF, accessed 6/09/2018).
[73] Daniel Currie Hall, "Interactive Sagittal Section", http://smu-facweb.smu.ca/~s0949176/sammy/ (accessed 5/30/2018) is a very well-done app mapping placement of the lips and tongue to numerous sounds.
[74] Daniel L. Everett, *How Language Began*, Liveright Publishing, 2017.
[75] Philip Lieberman and Robert McCarthy, "Tracking the Evolution of Language and Speech", *Expedition* vol. 49 no. 2 (2007), 15-20. https://www.penn.museum/documents/publications/expedition/PDFs/49-2/Lieberman.pdf (accessed and saved 6/02/2018).
[76] Ignacio Martinez et al., "Human hyoid bones from the middle Pleistocene site of the *Sima de los Huesos* (*Sierra de Atapuerca*, Spain)", *Journal of Human Evolution* 54(1) 118-124 (Jan. 2008), https://www.sciencedirect.com/science/article/pii/S004724840700139X?via%3Dihub (accessed and saved 6/10/2018).

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[77] Ignacio Martinez et al., "Auditory capacities in Middle Pleistocene humans from the *Sierra de Atapuerca* in Spain", PNAS 101(27) 9976-9981 (7/06/2004), http://www.pnas.org/content/101/27/9976 (accessed and saved 6/10/2018).
[78] Ann M. MacLarnon and Gwen P. Hewitt, "The evolution of human speech: The role of enhanced breathing control", *American Journal of Physical Anthropology* 109(3) 341-343 (7/01/1999), https://onlinelibrary.wiley.com/doi/abs/10.1002/%28SICI%291096-8644%28199907%29109%3A3%3C341%3A%3AAID-AJPA5%3E3.0.CO%3B2-2 (accessed and saved 6/10/2018).
[79] Bart de Boer, "Evolution of speech and evolution of language", *Psychon Bull Rev* 24:158-162 (2017), https://link.springer.com/article/10.3758/s13423-016-1130-6 (accessed and saved 6/03/18).
[80] W. Tecumseh Fitch and David Reby, "The descended larynx is not uniquely human", *Proc. R. Soc. Lond. B* (2001) 268, 1669-1675, https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1088793/ (accessed and saved 6/03/2018).
[81] David R. Carrier, "The Energetic Paradox of Human Running and Hominid Evolution", *Current Anthropology* vol. 25, no. 4 (Aug – Oct 1984) 483 – 495, https://www.journals.uchicago.edu/doi/10.1086/203165 (accessed and saved 4/22/18).