Evolution of the Physical Differences between Humans and Apes and their Impact

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Abstract

Anthropology, paleontology, archaeology, theology, philosophy, biology, and many other fields have attempted to answer the age-old question that every human has pondered – What makes us special? In particular, what separates us from our closest relatives, the apes? Driven by the accumulation of research and technological advancements, the question has evolved from "What makes such different animals alike?" to "What makes such similar animals different?" Human DNA is approximately 95%- 98.2% similar to that of our closest living relative, the chimpanzee (Smithsonian, 2010), and yet the differences in our successes and capabilities are outstanding. Some physical differences between humans and apes are clear; the brain, bipedalism, dexterity, and our ability to speak are among the most obvious and important. By investigating the lifestyle and evolution of early hominids, and by comparing ape and human anatomy and physiology, one can begin to understand the origins of physical divergences and discover how they led to human domination of our planet today.

Introduction

If you take a trip to the nearest zoo, there will likely be primate exhibits featuring chimpanzees, bonobos, gibbons and orangutans. We have far-removed ourselves from the great apes, labeling them as "lesser life-forms" even though taxonomically-speaking, *Homo sapiens* are classified as a great ape. Comparatively, we are rationale, emotional, and successful animals with capacities well beyond any other mammalian life form. Darwin was the first to propose in *The Origin of Species* that all animals have descended from a common ancestor, and he was also the first to propose in the *Descent of Man* that our closest relatives were the apes. Although Darwin was often ridiculed for his earth-shattering ideas, the discoveries of hominid remains and genetic comparisons since his time have only supported his theories. Most scientists would agree, we are apes, we were once ‘lowly apes;” before that we were “lowly fish,” and before that we were “lowly bacteria-like organisms.”

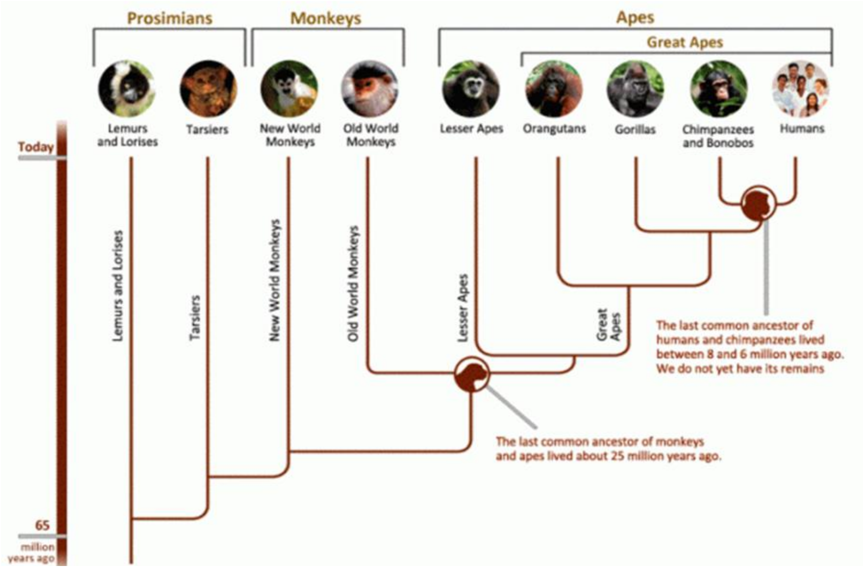
Evolution of Humans, Hominids, and Apes

It is clear that we are not lowly now, at least in terms of success. Although the term “success” is debatable, in terms of reproductive fitness, human populations continue to rise. In terms of dominion, we have become most wild animals’ worst nightmare. Humans (classified as *Homo sapiens*) have evolved physically and mentally to become the dominant species, and it is in this context that the word “success” will be used throughout this paper. Descent with modification from a monkey-like ancestor to man can be seen in the archeological records of early hominids, which although incomplete, shine light on the “steps” in our evolutionary path.

According to Darwin’s theory of evolution by natural selection, the driving forces of evolution are genetic variation, competition, and reproduction. Every species possesses some physical traits that have differentiated it from its ancestors. What Darwin did not know was that these physical changes were the results of mutations in the genetic code. A physical mutation is either beneficial for a species by allowing it to be better adapted to its environment, or detrimental to the fitness of a species, most likely resulting in extinction. By exploring the physical changes in hominids over millions of years, and directly comparing the differences between humans and apes today we can begin to not only understand what makes us special, but how we became special.

The physical forms of modern apes and humans have evolved over millions of years in a purposeful way, meaning in a way that enables them to better succeed in their environments. Chimpanzees and humans live in different environments and, therefore, exhibit different physiques. Some human apomorphies are our body shape, cranial features, brain size and morphology, limb length, longer lifespan, smaller canine teeth, reduced hair cover, elongated thumb and shortened fingers, pelvic structure, presence of a chin, curvature in spine, language, and advanced too making (Cela-Condo & Ayala, 2007). When these apomorphies diverged, how they diverged and why they diverged are the key questions anthropologists and paleontologists spend their entire career trying to answering.

Using DNA analysis scientists have discovered that we are most closely related to chimpanzees, followed by bonobos. In fact, humans are more closely related to chimpanzees and bonobos than either is related to gorillas or orangutans (Smithsonian, 2010). Darwin's theory behind the origins of man was often misconstrued, in that people assumed Darwin meant we descended directly from apes. Darwin's theory actually states that humans are *cousins* to the great apes. Humans began to diverge from a common ancestor about 7 million years ago (Cela-Conde & Ayala, 2007) as seen in figure 1, and everything in between then and now is called a hominid. Based on fossil records and genetic analyses, it has been concluded that this divergence occurred in East Africa. Figure 1 is misleading, however in that it suggests a trajectory path to Homo sapiens. Our physical design throughout time has not been linear by any means. The evolutionary tree, of which humans are a small part of, contains many branches or hominids, most going off in directions that have no living direct descendants today.



The last common ancestor of humans and chimpanzees lived between 8 and 6 million years ago. We do not yet have its remains

The last common ancestor of monkeys and apes lived about 25 million years ago.

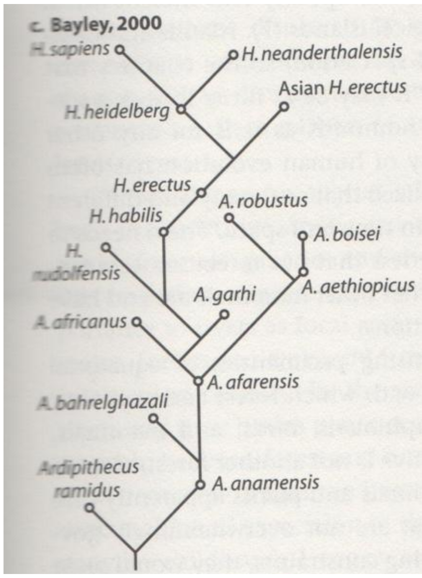


Figure 1 – Ape Evolutionary Tree. Smithsonian: Genetics, 2010

Figure 2 – Hominid Evolutionary Tree. Kingdon, 2003

As shown in figure 2, hominid evolution has included several intermediate species including several that have gone extinct. Although figure 2 paints a much more accurate picture of human evolution, no phylogeny trees can claim 100% accuracy due to an incomplete fossil record. Scientists have, however, found thousands of incomplete fossils of enough hominid species to begin building a tree diagram worthy of human evolution depiction.

In 1974, Donald Johanson and his team found “Lucy” one of the most complete and well-known specimens, dating to 3.2 mya (million years ago). Lucy is an Australopithecines afarensis, the species that yielded the first ever “family” grave of 13 individuals in 1975. For many years, researchers could not find a hominid fossil older than 4 million years, but it was believed that we diverged from apes 5-7 million years ago (NOVA, 2010). Geneticists estimated this time frame using a technique called the molecular clock, which looks at the nucleotide base differences between humans and apes. Since mutations occur at a constant rate, a computer can calculate how long ago the two species diverged based on these differences (mutations). The proof of the molecular clocks estimation came in 2001, when the oldest known fossil was found in northern Chad by Michael Brunet and his team. The fossil, nicknamed Toumaï, dates back to 6mya and the new species was called *Sahelanthropus tchadensis*.

Part 1: Bipedalism

Charles Darwin said in *Descent of Man:* **"**[I]t seems to me, that man with all his noble qualities – with his god-like intellect which has penetrated into the movements and constitution of the solar system – with all these exalted powers – Man still bears in his bodily frame the indelible stamp of his lowly origin" (Darwin, 1871). What Darwin is proposing, and what scientists agree on, is that the road to humanism began with bipedalism. Permanently walking on two legs is a major difference between humans and apes. When our "lowly" ancestors stood up, the word "hominid" was born and so was the great conceptual divide between zookeepers and the kept. Anatomical, ecological, and geographical examination illustrates how this evolutionary leap catalyzed success for the erect.

The Anatomy of Bipedalism

Anthropoid apes' normal gait is called "knuckle walking," a quadrapedal style in which the knuckles of the hand are used to stabilize body weight along with the feet. Humans walk on two legs, or bipedally, transferring weight only to the lower limbs and leaving the upper limbs free. These two ways of mobility are the habitual ways of locomotion, but humans can walk quadrapedally just as apes may walk bipedally. Apes are able to extend their spine when sitting, foraging and swinging through the trees and can eve walk on two legs indefinitely if they so choose. The answer as to why they do not permanently stand erect lies in their anatomy, especially the pelvis.

When a human stands erect, the spine, pelvis, and femur are aligned creating a natural plane that allows for stability and flexibility when walking (Arguaga & Martinez, 2006). An ape's pelvis and femur bones lie at an angle to their spine, which causes their legs to bow outwards and knees joints to flex. Even if an ape's femur were attached in a vertical plane, they would lose their balance because their legs would be too close together and the pelvis faces forward. The wideness of the *Homo sapiens* pelvis is another bipedal adaption. When an ape walks upright they swing back and forth awkwardly as they attempt to stabilize themselves. Apes choose to walk on four legs habitually because it is more comfortable and stable. In fact, the orientation of the pelvic bone to the spine and legs in apes is similar to that of other quadruped mammals (Arguaga & Martinez, 2006)**.**

Physically, the pelvic bone is the biggest difference between the walking apparatus in apes and humans. The overlying muscles also play a large role in gait. This is because muscles attach from bone to bone and so the orientations of the bones determine to some extent the orientations and functions of the muscles. In humans, the gluteus minus and medius act as abductors while in apes the same muscles act as hip extensors, limiting the types of movements either one can perform fluidly. Abductors act to decrease the torque between the pelvis and femur and retain a fairly stable center of gravity.

Natural selection has made several other anatomical adjustments to the human spine and skull over time to accommodate erect posture. In a quadruped, the force of its body weight is distributed to the limbs, while it's dorsally located spine is generally force free. By walking upright, human beings force their body weight onto their lower limbs and lower back. In order to accommodate this added weight the human spine has developed an “S-curved” composed of the thoracic and lumbar curves. When a woman is pregnant, the lumbar curve gets more pronounced as she deals with the extra weight of the child. Another modification is of the foramen magnum; the structure where the spinal cord attaches to the brain stem. The human skull extends backwards slightly, allowing the spinal cord to attach at an angle parallel to the face and the perpendicular to the floor. This is why a human must lift their head awkwardly as they crawl on four legs. Contrarily, an ape’s foramen magnum opens at an angle approximately 45° to the ground allowing them to look up and down comfortably as they traverse on four legs. When they stand erect they must push their head downward in an unnatural position to look straight ahead.

The structure of the foot is another vital adaption to walking in an upright position. An ape’s foot looks much like their hand since both anatomical structures perform similar tasks. A chimpanzee’s foot is flat and contains an opposable big toe that extends out laterally from the other toes allowing the chimp to use it as a stabilizer when walking (Arsuaga and Martinez, 2006) or grasp tree branches when climbing. A human’s foot is highly arched with non-opposable toes that extend outward. When humans walk the heel contacts the ground first and then as it rolls down the body weight is transferred through the arch. The big toe is last to leave the ground, acting as a final impulse to lift the foot up again (Arsuaga and Martinez, 2006).

Bipedalism in Hominids

A “missing link” cannot be deemed a hominid unless it stood on two legs. By reviewing fossilized bones and footprints of our ancestors, we can begin to understand how and then perhaps why bipedalism evolved. As might be expected, the anatomical structures of early hominids is somewhere between that of humans and apes, often leaning towards one or the other depending on the time of existence.

Hominids exhibited habitual bipedalism rather early after diverging from our common ape-like ancestor, suggesting it was some pivotal moment in the road to humanism. The oldest fossil to date, 6 million year old Toumaï of the genus Sahelanthropus tchadensis, was examined carefully for signs of bipedalism since it is believed we diverged from the common ancestor 6-7mya. Brunet (2001) and his team concluded that Toumai was in fact a habitual walker based on the angle of the foramen magnum. Hominds of the genus Australopithecus, like Lucy, that lived 4.5-3.5 mya may have been able to climb trees as well as walk upright. Lucy’s hips were wide, faced upwards, and she had a long femur bone that attached in a planar fashion like that seen in humans. Lucy’s fossils showed that she was ape-like from the hip up and human-like from the hip down, suggesting that she was at home on the ground and in trees (NOVA, 2010). Perhaps Lucy slept up in the trees at night to evade predators, or climbed up to reach fruit.

In 1976, paleoanthropologists found the famous Laetoli footprints in Tanzania. They date back 3.5 million years, when Australopithecus was roaming the East African continent. The prints indicate fully developed bipedalism. Seismic graphs indicate a highly developed arch in the foot and the big toe is clearly facing forward just as it would in humans. The prints consist of two sets, one smaller on the left and one larger on the right. Seismic data from the smaller footprints show that the hominid was either limping on the right leg or they were leaning against the larger hominid.

Evolution of Bipedalism and Impact

Although minor dispute of details is prevalent, the scientific community agrees that bipedalism evolved rather early after diverging from apes. The real question was the reason for it, especially since there are very few bipedal mammals today. One common theory is that height advantage allowed early hominids to peer over the tall savanna grasses to avoid predators and locate prey. This hypothesis has a hole, however, because animals are naturally selected to an ecological niche, not just an aspect of an environment ((Arsuaga & Martinez, 2006). The theory also does not explain why many other animals in the open savanna are still successful quadrupeds after millions of years of evolution. Furthermore, it is also believed that our earliest ancestors habited a forest biome, which lacked copious amounts of tall savanna-like grasses.

Another common theory is that bipedalism evolved so that the hands were freed to make a hunter gatherer lifestyle as efficient as possible. Although walking on two legs did free the hands, the fossil record shows that millions of years passed between the evolutions of erect posture and nimble, human-like hands *(*Arsuaga & Martinez, 2006). Other theories include: "the upwardly mobile" hypothesis that arboreal apes began to run on tree branches as opposed to swinging and climbing (Tuttle); phallic display by males allowed for an advantage in female sexual selection (Tanner); height-advantages were synonymous with intimidation displays for sexual selection and predator evasion (Jablonski & Chaplin); an aquatic lifestyle was adapted to expand our food supply (Westenhofer, Hardy & Morgan); a chance "attention grabber" led to imitation, spread to become a species culture, and then was naturally selected for (Dawkins) (Kingdon, 2003).

A hypothesis waiting to be disproven is one of Peter Wheeler (1985), in which he states that standing erect aided in thermal regulation. By standing upright, an animal can avoid direct sun rays, especially at the zenith. Also, gaining height would allow an animal to take advantage of breezes. Evidence for this theory can be seen by loss of body hair and the development of cutaneous sweat glands. Humans living in extremely hot climates today wear clothing to protect themselves from sunburns just as animals that are exposed to direct sunlight have hair on their backs.

The hypothesis that seems to carry the most weight is that it is more energetically favorable to be bipedal when travelling long distances. All of this interplay between physical forces and the anatomical structures of the human walking apparatus result in the human bipedal locomotion which is much more efficient (more result with less energy expended) than apes can effect. A study conducted by Herman and his colleagues found that human walking uses approximately 75 percent less energy and burned 75 percent fewer calories than a quadrupedal-walking ape and a bipedal-walking in chimpanzees. Either way, chimpanzees just aren't meant for walking. They are adapted to live within the rainforest and climb trees.

Humans are adapted to traverse. As early hominids began migrate there was less of a need to climb trees and more of a need to walk long distances from resource to resource. Standing upright seemed to be an adaption to this change in lifestyle (Arsuaga & Martinez). Recent data has shown that this was not necessarily a conscious choice. “We” did not *leave* the rainforest, the *rainforest* left “us.” Ten million years ago Africa was a lush, wet, rainforest. Since then, it has been on a drying trend (NOVA, 2010). As a result, the rainforests began to slowly disappear. The ape-like ancestors that stayed in the shrinking forests are the chimpanzees we see today, and the ape-like ancestors that braved the environments outside the forests have become many species, in which *Homo sapiens* are one.

Although bipedalism was an important landmark in hominid evolution, its impact on succeeding events is often debated. How much of a catalyst was erect posture on other adaptions thought to be landmark? Was it just another change in a long line of interconnected adaptions or was it the prerequisite to becoming human? Although almost all of the answers we can suggest at this point are conjecture, with the benefit of hindsight it is safe to say that freeing the hands as walking apparatus allowed them to evolve into the most powerful and flexible tools of any species.

Part 2: Dexterity

"Visitors to the zoo indulge in transports of delight at the way an elephant reaches for an apple with it's trunk, and become ecstatic at seeing a squirrel use its paws to eat, but give not a moment's thought to the ineffable capabilities of their own hands" (Tuttle, 1993). There are entire literary works on the human hand. It is an incredibly adapted tool in accomplishing tasks no other animal can perform and humans with all our digital inventions could not duplicate an artificial hand mirroring the real thing. A hand expresses emotion, allows for intricate motor activities, and is a primary beacon to the outside world.

The Anatomy of Dexterity

Chimpanzees have hands adapted for locomotion and tree climbing. They have long, curved fingers to grip tree limbs and their short thumbs are not as opposable as the human hand because they do not perform nimble tasks. The human hand has much shorter fingers, a longer highly-opposable thumb, and is much more muscular with thicker bones. The relative lengths of the phalanges in humans allow for opposition, a defining characteristic of dexterity. Opposition occurs when the palm surface of the thumb meets the palm surface of another phalange. This allows humans to use the fingers with unmatched precision. Many people have experienced how quickly their dexterousness disappears just by putting on a pair of thin gloves and trying to button up a jacket. Since an ape’s fingers are too disproportional for palmar opposition, they must use the side of their finger to stabilize an object when picking it up.

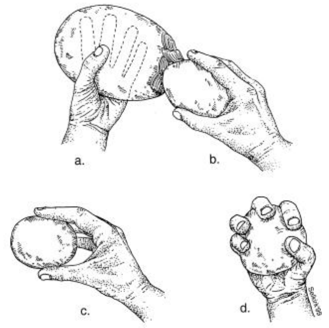
The grips between humans and apes are profoundly different. When chimpanzees hang on horizontal or vertical supports they either use the hook grip or diagonal grip, respectively. These grips involve the flexing of the four fingers but the thumb is not strong or opposable enough to wrap around the support to squeeze it against the palm. They use these grips when flailing sticks, but because the thumb cannot be used, and because the thumb and index finger cannot overlap, the stick tends to slip out of the hands.

There are two hand grips that are unique to humans, the power grip that is possible because of the robustness and muscularity of the hand and the precision grip, which is possible due to opposition and finger mobility. The human hand is much more flexible with a greater range of motion. *Homo sapiens* are also able to move their fingers independently of each other and the tips of the fingers exhibit much more strength that the fingertips of apes. This allows the nimbleness required to handle small and delicate objects. Another integral component of object manipulation is the cupping of the hand, which apes cannot perform due to their finger inflexibility and strength.

Dexterity in Hominids

A fossil is categorized as a human, pre-human, or ancient ape depending on a number of factors. Along with bipedalism, one of the greatest deciding factors is the hand morphology and presence of tools at the archeological site. When looking at the fossils of hominids, scientists look for the thickness of the bones, the curvature of the phalanges, and the length of fingers and thumb. In 1960, bones of a 1.75 million year old hominid were found in Olduvai George, Tanzania. The species was named *Homo habilis*, or handy man, since the hand was determined human-like enough to make tools and tools were discovered around the site. *Homo habilis*' hand exhibited some features of an ape hand, but had a long thumb that had a high range of motion that could likely flex powerfully at the tip (Marzke & Marzke, 2000).

The complexity of tools indicates to some extent the intellectual and social capacities of a species. A hominid isn't given the distinguishing title of *Homo* until tool-making abilities can be proven. Although hominids such as Lucy and other *Australopithecus* were *tool-using*, like apes, they were not *tool-making*. The difference between these two terms is in the brain. Tool-making consists of higher-level thinking such as abstractness and imagination (Tuttle, 1993). An abstract tool-maker must be able to take an object and turn it into a tool that does not necessarily resemble the original material. An evolution of tools can be seen along with the evolution of the hand and brain in hominids. The very first stone tools are known as Oldowan, a name which derived from the first site where *Homo habilis* bones were found.



Homo habilis is the oldest species in the genus *Homo* because they were able to make complex and abstract tools (Arsuaga & Martinez, 2006). The tools they made were *choppers*, or tools used for cutting meat and bones. This was important for human evolution because the canines were beginning to regress in the pre-human species. *Homo habilis* were in a sense, given a cutting edge against other hominids that existed at the time.

Evolution of Dexterity and Impact

The evolution of the human hand and the complexity of tools are positively correlated. Although the cause of hand evolution has been debated, most scientists agree that tool use was the primary catalyst. Young (2003) proposed that picking up and throwing stones at adversaries was the first use of tools by pre-humans. This would allow for direct sexual selection that would pass down the genes for dexterousness hands. Although it is believed that pre-humans were not pair-bonding, females would likely choose a male who could defend his group, face off other suitors, obtain more meat etc. In general the male who could handle a tool would be dominant.

Through culture, imitation, an evolution a family of early pre-humans could have developed an unmatched prowess at throwing rocks and swinging clubs. The more aptitude a group had for dexterousness, the more successful they would have been at overthrowing other groups in territorial disputes. This would ultimately lead to greater access to reproductive females and food. Once dexterous hominids became the predominant population, they began using tools for an array of needs, like hunting, food preparation, and fire making (Young, 2003). Accurate and powerful clubbing requires a power grip of the hand and precise throwing requires the precision grip. It seems reasonable to assume that our two unique grips evolved from this illustrated scenario. Young (2003) also suggests that dexterity co-evolved with bipedalism since efficient clubbing and throwing requires a whole body twisting motion that requires thrusting from the legs and balancing weight on two legs.

It is also believed that making stone tools evolved the hominid hand into that it is today. Although sharpening rocks does not seem particularly difficult, the focus it takes to stroke a rock repeatedly with another rock requires a great amount of concentration. Even the bonobo, Kanzi, who is famous for his intelligence could not be taught to make at tool that resembled a chopper (Arsuaga & Martinez, 2006). Perhaps it was not his intelligence that hindered him but the morphology of his hand. It would have taken a very robust hand to withstand the forces needed to make an Oldowan tool. The hominid would have had to turn the stone in their hand and then grip it securely while they beat it repeatedly with another stone held firmly in another hand.

Part 3: Brain Cavity/Brain

If someone were asked what they thought the most important difference between humans and apes was, they would most likely answer the brain or the mind. If they happened to name some functional trait, like language or tool-making, they would have also named a primarily brain-using activity. Indeed, humans are the most intelligent organisms on planet earth. We are the only animals capable of putting men on the moon, writing symphonies, and filling libraries with imaginative stories and explorations of historical events. How and why did we evolve such unmatched capabilities?

Brain Cavity/Brain Anatomy

The three main portions of the brain are the cerebrum, cerebellum, and brainstem. The cerebellum is responsible for “automatic” functions, such as maintaining heart beat and breathing while the cerebrum holds the key to higher-level functions. In humans, the cerebrum is split up into the right-hemisphere and the left hemisphere. The right hemisphere is responsible for spatial abilities, face recognition, visual imagery and music; while the left hemisphere is responsible for language, mathematics, and logic.

When keeping body mass constant, the human brain is approximately 1350cc, while the ape brain is around 450cc (Cela-Conde & Ayala, 2007). Our brains are larger, more complicated, and more interconnected, largely due to our large cerebrum. Apes have a groove in their brain called the lunate sulcus, located near the posterior, which separates the vision portion of the brain from complex thought. Humans do not have such a structure since it has moved too far back on the brain's surface to see.

Another important difference between humans and apes, is brain development. Chimpanzees brains are 90% developed by age three (NOVA, 2010). The human brain isn't fully developed until age 25. The reason for such a discrepancy will be discussed when looking at hominid brain development.

Hominid Brain Cavity/Brain

Soft tissues like the brain do not fossilize, and so scientists use the cranial space to measure the volume of the brain. They are able to do this because the brain occupies the entire cranial cavity (Arsuaga & Martinez, 2006). Brain cavity fossils have been found for many of the pre-human species and their brain mass has been estimated. The following is an incomplete table of this information with the years the species existed:

Table 1: Encephalization in Hominids (modified from Arguaga & Martinez, 2006)

Years Ago	Species	Brain Volume (cc)
4 – 2.7 mya	Austalopithecus afarensis	426
3 – 2 mya	Australopithecus africanus	436
2.2 – 1.3 mya	Paranthropus boisei	508
2.2 – 1 mya	Paranthropus robustus	523
2.2 – 1.6 mya	Homo habilis	610
2.1 – 1.5 mya	Homo ergaster	805
2 – 1.3 mya	Homo erectus	900
400,000 – present tya	Homo sapiens	1350

The evolution of brain size is clearly evident from this table, but care should be taken not to directly correlate brain size with intelligence. The species *Homo neanderthalensis* had a larger brain that *Homo sapiens*, at approximately 1500cc. Would Neanderthals have gone extinct if they were smarter than their cousins? After heavy study of Neanderthal remains and the recent sequencing of their DNA, scientists have confirmed that they were not at the intellectual level of pre-humans. They did not build fires, leave behind cave drawings, or even communicate with language (Bickerton, 2009). So although their brain was bigger, their brain did not have the interconnectedness exhibited by the brains of *Homo sapiens*.

Before recently, it was believed that bipedalism evolved before the brain since *Australopithecus* walked bipedally but had a brain size equal to an ape’s. Researchers are discovering that they were actually more intelligent by studying the location of the lunate sulcus. How could they do this without having a fossilized brain to study? The answer lies in the brain’s endocast, or the outer covering, that leaves an impression of the brain on the inner skull surface.

The endocast of the famous Taung child, a young *Australopithecus africanus*, showed that the lunate sulcus was moved farther back than that of an ape. This would suggest the child's species exhibited more problem solving abilities than an ape with the same size brain.

Brain development of a hominid can be determined by looking at the relative brain sizes of a child and an adult of the same species. It was determined that the brain of the children Salam and Taung were developing slower than that of a chimp resulting in a prolonged childhood. How could remaining a child be beneficial in the harsh East African environments millions of years ago? The answer lies in the birth canal/skull size relationship. The brain and skull of an adult human and hominid would have been too large to pass through the birth canal. Development of the brain slowed so that the baby's head could successfully be born and then continue to develop.

Brain Cavity/Brain Evolution and Impact

An interesting connection was noted among primates that gut size and brain size were inversely proportional. Why was this so? The human brain utilizes approximately 20% of the body's basil metabolism, which of course is supplied by ingested food. Other organs that require high energy inputs are the heart, liver, kidneys and gut tract. In order to increase the mass of the brain, another high-cost organ had to be sacrificed. The heart, liver and kidneys are rather non-negotiable, but the gut may be reduced rather significantly by changing the diet allowing the brain to have access to more energy. It has been hypothesized by Aiello and Wheeler (1995) that humans diverged when the diet changed to include more meat. Herbivorous animals have a much larger digestive tract and energy requirement to break down the high cellulose content in plants. It is interesting to note that researchers consider the Neanderthal a strict meat eater, which may play a role in their large brain size.

A natural question is why hominids began eating more meat because it was highly unlikely a conscious choice. The answer lies in first studying the environments that existed millions of years ago in East Africa. Ten million years ago Africa was a lush, wet, rainforest. Since then, it has been on a drying trend. The rainforests began to slowly disappear, at first creating a lovely mosaic of lakes, rivers, and valleys. Apes today inhabit the rainforests, but what if they were to disappear? Our ancestors had to adapt to changing landscapes, and that included changing the diet. The rainforests provided plenty of nuts and fruits for our ancestors and so it was believed that we were strictly herbivorous. When the trees began to disappear hominids had to begin looking at the food source the plains could provide; meat.

As we began changing out diet, our large teeth and jaw muscles that were used to crack open the shells of nuts began to regress. An ape's mastication muscles are so large they weigh down the skull, inhibiting it to expand. If you look at a baby's skull it is broken up into pieces that allow the skull to mold when exiting the birth canal. Because humans do not have jaw muscles that weigh down the skull, our brain cavity may continue to grow allowing for larger brains. So in a sense, eating meat allowed for the coevolution of the brain cavity and the brain.

If all of the early hominids were forced to eat meat, and therefore develop larger brains, why are Homo sapiens that only species to survive to today? By examining table one it is clear that East Africa was full of several hominid species coexisting. In fact, several hominid species flourished in East Africa twenty-five times longer than *Homo sapiens* have even existed (NOVA, 2010) How did the genus *Homo* develop such a significantly larger brain that the other geneses? Rick Potts, the director of the Smithsonian's Human Origins Program, has made a hypothesis that would explain this.

Although the weather in Africa over the past ten million years has undergone a general drying trend, the East African’s rift valley has experienced burst of environmental change. Geologists know this by studying the strata of the nearby oceans floors and continental rock layers. Layer of fossilized diatoms, small water-dwelling phytoplankton, have been identified in some strata of the rocks and not others. This indicates that giant lakes appeared and regressed from the rift valley, sometimes in the span of just 1,000 years. The rock strata also tell geologists that there were times of volcanic activity.

Rick Potts suggests that it is this drastic change in environments that separated the genus *Homo* from the rest. The *Homo* hominids had larger brains that were used to problem solve and adapt to new environments. In essence, human beings are adapted to change, and therefore, live and prosper under a variety of environments. The other genus’s exhibited greater problem solving abilities than apes, but could not adapt quick enough to the extreme environmental fluctuations.

With larger brains and a greater need for adaption, the first stone tools began to appear. The *Homo* genus began building fires, hunting efficiently, and cutting the meat to extract the most nutrients. *Homo erectus* began to migrate out of Africa and colonize Asia and Europe. They could prosper in instability. They could search out new opportunities. This is what truly makes our genus special.

Concluding remarks

With the development of the brain, we begin to see the mental aspects of humanity. Caring about our history, being shy about nakedness, caring what someone thinks about you, and empathy are truly human emotions. Some scientists believe that communication and language was another hurdle that separated *Homo sapiens* from other *Homo* hominids. The FOXP2 gene, responsible for speech was absent from the Neanderthal sequence. They probably could hardly compete with another species who were communicating to solve problems like hunt, travel, and make decisions.

Although it would be nice to assume a neat sequential order of the evolution of certain physical differences, it is not so. Evolution rarely has a cause and effect rhythm, but is an interconnected web of co-evolutionary relationships. For example, by walking bipedally, the hands were free to use tools such as spears to hunt down prey as the diet changed. The hands evolved a nimble ability to design and make intricate weapons, and an ever-growing brain allowed for the social and mental capacity to see it all through and the language genes to communicate in bringing an animal down. An emphasis should be placed on the intricacy of evolution by natural selection. One adaption probably did not cause the others, but they each played an integral role in the co-evolution of each other. This is a feedback model that has eventually led to the sole existence of *Homo sapiens*.

Works Cited

Aiello L.C. and P.Wheeler. 1995. The Expensive-Tissue Hypothesis: The Brain and the Digestive System in Human and Primate Evolution. Current Anthropology. Vol. 36, No. 2 (Apr., 1995), pp. 199-221

Arsuaga, Juan Luis and I.Martinez. 2006. The Chosen Species: The Long March of Human Evolution. Blackwell Publishing

Bickerton, Derek. 2009. Adam's tongue : how humans made language, how language made humans. Edition 1st ed. New York : Hill and Wang.

Cela-Conde, J.C. and F.J. Ayala. 2007. Human Evolution: Trails from the Past. Oxford University Press.

Ilana, Johanson. 2010. Great apes & humans : the ethics of coexistence. Washington : Smithsonian Institution Press, Zoo and aquarium biology and conservation series. http://www.indianajohnson.com/

W. E. H. Harcourt-Smith & L. C. Aiello. 2004. Fossils, feet and the evolution of human bipedal locomotion. Anatomical Society of Great Britain and Ireland. 204, pp403–416.

Pontzer,Herman, D.A. Raichlen and M. D. Sockol. 2009. The metabolic cost of walking in humans, chimpanzees, and early hominins. Journal of Human Evolution. Volume 56, Issue 1. Pages 43-54

Potts, Richard. 1999. Variability selection in hominid evolution. Wiley-Liss, Inc Volume 7, Issue 3, pages 81–96, 1998

Wheeler, P.E. 1984. The evolution of bipedality and loss of functional body hair in hominids. Journal of Human Evolution. Volume 13, Issue 1, January 1984, Pages 91-98