The Price to Pay for Evolutionary Success

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INTRODUCTION

Evolution can be defined as the genetic change in a population over time. Natural selection is a major force of evolution when environmental factors dictate which genes are beneficial and, therefore, are passed to future generations. Theory states that those genes that are the most beneficial under current circumstances result in an organism with a better chance of survival and/or increased reproduction and are therefore better represented in future generations. Evolution by natural selection leads to adaptations that increase survival and reproduction in a given environment. Humans have undergone many adaptations over millions of years to become the species they are today. As humans make technological and medical advances they have the ability to alter and manipulate their environment, indicating that they have a certain control over their own evolution.

Humans, like other organisms, are the product of billions of years of evolution, and have been evolving for the past 4-5 million years as a species, resulting in the influential and powerful species they are today. Humans have become very well adapted to many different environments around the world, resulting in their evolutionary success. The most distinguishing characteristic that sets humans apart is their form of locomotion—bipedalism. Bipedalism is a form of locomotion in which the organism stands and moves on two legs. Birds and some reptiles are often seen on two feet, but it is not their primary form of locomotion. Mammals are typically quadrupeds, meaning they stand and move on four legs. Primates demonstrate an ability to stand on two feet for short periods of time (facultative bipedalism), but humans are the only species adapted to obligate bipedalism. Humans evolved to stand and move on two feet, diverging from other primates and leading to the modern human. There are numerous hypotheses why humans stood upright; most common are the savanna and water hypotheses, but neither provides definitive evidence. While bipedalism has allowed humans to thrive in their environment, it has also created numerous medical problems. The spine and pelvis are two structures that were greatly altered as humans stood upright. The changes that took place have increased medical problems specific to humans, particularly osteoporosis-related spinal fractures and difficult childbirth. Both of these problems can be, and historically have been, deadly to humans. These dilemmas are often times overcome with medical intervention and are no longer a major cause of death. Modern medicine is reducing any pressure to fix these problems through natural selection, and there is a possibility that humans will depend on medical advancements for survival. Modern medicine, and the ability to acquire it, may become the major selective force as humans continue to evolve.

BIPEDALISM

Many human health problems are caused by our upright posture. Humans have adapted a unique form of bipedalism as their primary locomotion (Latimer 2005; Morgan 1994). There are other animals that exhibit bipedal locomotion, such as kangaroos and ostriches, but their center of gravity is evenly distributed around their points of contact with the ground due to the angle of their bodies (Morgan 1994). Their spines and bodies are not perpendicular to the ground, but parallel or nearly parallel. The human spine evolved to be perpendicular with the ground, causing their center of gravity to rotate 90°, resulting in the unique bipedalism seen in humans (Fig. 1; Latimer 2005). The vertebral column seen in quadrupedal animals acts as an arch between the legs (Morgan 1994). The weight of the internal organs is suspended from the spine and distributed along the length of the vertebral column. When the spine of humans rotated to be perpendicular with the ground, an 's' shape formed to support the weight of the head and upper body. Humans are born with a single convex arch along the entire spine. This is lost once the baby learns to sit up, resulting in the concave arch found beneath the neck. Once babies begin standing and walking, a second concave arch develops in their lower back (Fig. 1). These two curves are essential for humans to be able to balance and move efficiently on two feet.

Six to seven million years ago human ancestors began walking upright, creating the split between human and ape lineages, and 3.2 million years ago bipedalism was the primary form of locomotion (Ackerman 2006; Morgan 1994). Bipedalism as a primary form of locomotion was supported by the discovery of Lucy, the fossil remains of an obligate bipedal *Australopithecus afarensis*, an ancestor to modern humans. What would cause a certain group of apes to change their stance? Although there are many hypotheses why humans evolved to walk on two feet the most commonly accepted are the Savannah hypothesis and Aquatic hypothesis.

The Savannah hypothesis states that a group of apes stood upright to survive in the open savannah (Morgan 1994). Morgan (1994) discusses the many variations of the Savannah hypothesis. Reasons include hunting for meat, grazing on grass and seed plants, finding sexual partnerships, and being exposed to direct sunlight. The first idea, that humans walked on two feet to hunt animals, was proposed by Dart in 1953. This was disproved when scientists discovered, through fossils, that bipedalism came before hominids evolved big brains or developed the ability to use tools to kill (Morgan 1994).

The seed hypothesis suggests that if apes entered the savannah to eat seeds, the low nutritional value of seeds would require high movement rates to allow for increased foraging. Therefore, the apes would not waste time to return to all fours but use both hands to grab and eat. This is seen in grass-eating gelada baboons and was believed to have been used by the humans' early ancestor. This is further supported by fossil records that show a decrease in canine size and bunodont molars, characteristic of seed eaters. This hypothesis was questioned, and later dismissed, when geladas were observed with three points of contact with the ground, shuffling along on their bottoms (Morgan 1994).

Lovejoy suggested that some apes formed pair bonds where two apes were monogamous and shared responsibilities. Lovejoy hypothesized that males may have wandered further away for food. To bring some back for his mate, a male ape carried the food in both hands and walked back on two legs. This was thought to have arisen in the forest, where apes typically live, but then the males began going farther into the savannah for food. There were many problems with this hypothesis, making it an unlikely reason for obligate bipedalism. Male apes rarely offer their food to females, even in pair-bonding relationships. Additionally, when gorillas reach for something or are carrying something, they support themselves with two legs and an arm. They do not immediately resort to bipedalism (Morgan 1994).

Another variation of the Savannah hypothesis suggests that apes stood upright to reduce the amount of direct sunlight on their body. A quadrupedal ape in the savannah during the day exposes 17% of its total body surface area to the sun. However, only 7% of the total body surface, specifically the head and shoulders, is exposed when upright, resulting in a cooler body temperature. This is supported by the hair remaining on a human's head, which would protect the sun-exposed skin. A major objection to this idea is that apes must exert much more energy to stand upright, which would have negated the cooling effects of the decreased sun exposure. The many different Savannah theories try to explain the reason why humans chose to stand up on two legs, but all fail to address why humans are the only obligate biped primate (Morgan 1994). If standing upright was advantageous, why has *Homo sapien* been the only species to evolve such a mechanism?

An alternative hypothesis for human bipedalism is the aquatic hypothesis first published by Alister Hardy in 1960 (Morgan 1994). In 1984, Partridge Films released a documentary that showed proboscis monkeys walking upright through chest-high water. These monkeys live along the coastal swamps of Borneo in the mangrove trees. They are occasionally seen on land but spend most of their time in the trees or in the water surrounding them. They are very good swimmers and can swim for long distances, but when the water is shallow, they wade on two legs. If the water recedes enough at low tide, these monkeys can be seen on land walking on either four or two legs. It is striking that these monkeys exhibit bipedalism that is markedly different than other ape bipedalism. Apes, specifically gorillas and chimps, display bipedalism over short distances, sometimes sideways accompanied with loud noises, usually indicative of a ritual or threat (Morgan 1994).

The proboscis monkey calmly walks on two legs to get from one place to another. The proboscis monkeys have adapted to bipedalism because they were forced to choose between breathing while they walk through water, swimming, or drowning. With the water surrounding them, if they chose to remain on four legs, their heads would be underwater, inhibiting breathing. If they walked and waded on two legs, their heads would be above the water, allowing them to breathe and also free their arms to carry young or food. Additionally, walking is more energy efficient than swimming and frees the hands for carrying objects (Morgan 1994).

By developing bipedalism in the water, there is less strain on the spine and less weight on the lower back. There is also more stability while wading through water, resulting in more coordinated movement. In the savannah, there seem to be disadvantages, like unstable equilibrium and skeletal and musculature strain, that are avoided in an aquatic environment. On land, bipedalism would have become advantageous only after thousands of years of struggling to operate upright (Morgan 1994). Apes are unable to stand continuously on two feet because their hip and knee anatomy only allows them to walk with flexed hips and knees (Sockol *et al.* 2007). To maintain their center of gravity above their point of contact with the ground, they must bend they knees and hips (Lovejoy 2005). This method of walking is energetically costly, so many apes do not choose this for long periods of time. This illustrates the difficulties early humans would have faced had they begun walking upright on land.

Some objections to the aquatic ape hypothesis include that apes have an aversion to water, so they would not have chosen to move to an area covered in water. The areas where Lucy and other fossil remains were found are not muddy or even remotely wet today (Morgan 1994). Scientists have discovered that from about 7 million years ago until 70,000 years ago a marine basin covered northern Afar. The sea flooded into the area and was contained, and after millions of years it evaporated, resulting in the desert found there today. Afar is a region of Ethiopia for which *Australopithecus afarensis* was named. The time frame of the marine basin correlates with the time given for the period when the ape/man split occurred. When the sea flooded, a group of apes were isolated from the population, creating an opportunity for rapid evolutionary change. *Oreopithecus*, commonly referred to as swamp apes because their fossil remains were found preserved in mud, provide further support for this hypothesis. They were once thought to be early ancestors of humans because of fossil resemblance, but they have since been removed from the human lineage. It is possible that this is a case of convergent evolution – where two different species evolve similar characteristics because of similar environments. It is interesting that the *Oreopithecus* pelvis is characterized by short iliac bones, common in most aquatic mammals and in humans and their ancestors. This suggests that by living in a marshy environment *Oreopithecus* became a good swimmer, bipedalist, or both (Morgan 1994).

Regardless of why humans stood upright, there were significant changes to the anatomy, especially the spine and pelvis. Bipedalism has created different orientations of these features, which have, in turn, caused different health problems for humans today.

ANATOMY AND AILMENTS

The Vertebral Column

The vertebral column acts as an arch across the sets of legs to support a quadruped but has become the weight bearing column of a biped (Morgan 1994; Ackerman 2006). Bipedalism results in different morphological and mechanical demands of the spine, and these differences are believed to contribute to spinal diseases in humans (Hernandez *et al.* 2009). The human spine has evolved two additional concave curves in the upper and lower spine. To support the weight of the head, a curve in the neck vertebrae developed and to balance the weight of the upper body over the hips, a curve in the lower vertebrae developed (Ackerman 2006). There are four curves in total: the primary curves (thoracic and sacral) and secondary (cervical and lumbar; Fig. 1). The secondary curves evolved as a result of bipedalism. The human spine differs from other apes considerably in both shape and mineral composition.

Shape and Lower Back Pain

Humans have undergone an invagination of the vertebral column into the thorax to help support the spine (Lovejoy 2005). Compared to an ape spine, the human spine has one less thoracic vertebra (as does the orangutan), but the total length of the thoracic spine is not significantly different after body mass is considered (Hernandez *et al.* 2009). Based on the lower backs of primates, they are grouped into "short-back" or "long-back" (Lovejoy 2005). Short-back primates are those that utilize suspensory locomotion, made possible by a reduction in the length of the free lumbar column and change in thoracic shape. Great apes are considered short-back primates because their lower spine has no flexibility because of the direct attachment of the thorax to the pelvis. The shortened lumbar spine was an arboreal adaptation, which has, in turn, hindered their ability to walk on two legs (Lovejoy 2005). Humans have a longer and more mobile lower spine allowing for their bipedal lifestyle.

The change in the lower back is necessary for a bipedal lifestyle. Without the additional lumbar curvature the center of gravity would not be situated above the hips, and, therefore, not above the feet supporting the body (Ackerman 2006). This change in structure greatly altered the vertebrae themselves. The lower vertebrae experience increased pressure due to the weight of the vertebrae above them pushing down, exaggerated by the lumbar curve. This can cause pinched nerves and/or the disks between the vertebrae to herniate or bulge outward. Lower back pain accounts for more than 15 million doctor visits each year and over $100 billion spent on back pain each year in the United States (Ackerman 2006; Duthey 2013). The Global Burden of Disease estimated in 2010 that lower back pain is one of the top ten causes of disability worldwide and is the leading cause of activity limitation (Duthey 2013). Pain management is the main treatment option, but surgery is also used to treat lower back pain.

Mineral Composition and Osteoporosis

Humans have a higher percent of cancellous bone volume and porosity than other apes, meaning that they have a higher percentage of spongy bone (Hernandez *et al.* 2009). While the vertebral body of humans is greater than other ape species, the volumetric bone mineral density of humans is significantly less than that of all other ape species. Human vertebrae have a greater surface area than apes (Hernandez *et al.* 2009; Latimer 2005).

Additionally, young adult human thoracic bone density is less than that of other species which have reached adulthood. This suggests that when humans mature to adulthood, and bone density decreases due to age, humans are already at a disadvantage because of lower bone density in young adulthood. While increased vertebral size may benefit the bipedal lifestyle by increasing the surfaces for muscle attachment to absorb more forces exerted on the vertebral column, this tends to decrease vertebral density (Cotter *et al.* 2011). These differences may also contribute to relative osteoporosis in humans (Cotter *et al.* 2011).

Osteoporosis is low bone mass and structural deterioration of bone tissue, which leads to bone fragility and increased risk of fractures (Karasik 2008). Osteoporosis contributes to over 1.5 million fractures annually in the United States. Spontaneous fractures of the vertebrae are the most common osteoporosis-related fracture in humans and are not reported in wild or captive apes (Cotter *et al.* 2011). These fractures are not due to falls or trauma but are related to the strength of the vertebral bones. Osteoporosis may be prominent in humans because of the increased surface area of skeletal tissue (Latimer 2005). The larger surface area of the bone allows for more mineral loss, which can lead to osteoporosis when mineral reabsorption slows with increasing age. Osteoporosis is also influenced by the peak bone mass and strength achieved in adulthood (Cotter *et al.* 2011). Young adult human vertebrae have less strength compared to a young adult apes with similar bone mass and body mass, based on a thinner vertebral shell (Cotter *et al.* 2011). When age-related bone loss occurs, more weight is put on the vertebral shell, which can lead to fractures.

Wild and captive apes do experience age-related bone loss like humans, but they are not at risk for fractures (Cotter *et al.* 2011). Apes have stronger and higher density vertebrae than humans at a younger age, decreasing the risk for fractures and reducing the negative effects of decreased bone density at older age. Osteoporosis is not subject to natural selection because it generally occurs after child bearing years. While a genetic basis might exist for osteoporosis, because it is expressed after reproduction, the genes can still be passed on to the next generation. However, modern medicine is able to manage this problem through different remedies, like pain management and surgery (Osteoporosis and Spinal Fractures 2010).

The Pelvis

Despite all the changes to the spine, bipedalism would not be efficient without alteration of the orientation, size, and shape of the pelvis (Lovejoy 2005). Chimps and gorillas must flex the hip joint in order to center their mass over their feet, which requires metabolic energy. Other great apes, besides the human, have a long thin paddle-like pelvis while humans have a flat saddle-shaped pelvis (Fig. 1 and 2) that is rotated 90 degrees to accommodate bipedalism (Ackerman 2006). The alterations to the pelvis not only shifted the weight of the trunk directly over the pelvis and legs but also provided more space for attachment of large leg muscles. These changes made walking on two legs more efficient, but they made childbirth much more difficult. Other aspects of the pelvis were altered in order to accommodate childbirth. In African apes, the pubic symphysis fuses by the end of adolescence, but in humans this does not occur until the end of the third decade (Lovejoy 2005). This delay prevents premature fusion that would further restrict an already complicated birth process. As humans continued to evolve, there were pressures placed on birthing mechanisms due to their bipedal body structure.

Childbirth

Chimps and other great apes have a pelvis that allows for a straight birth canal (Ackerman 2006). The baby primate also emerges face up, which allows the mother to pull the baby out and easily clear its airways if there is any trouble. The birth canal is oval-shaped the entire length. When *Australopithecus afarensis* adapted to bipedalism, the pelvis shifted to accommodate the orientation of the body, which changed the parameters of the birth canal. *A. afarensis* exhibited a pelvis that has qualities of humans with a wider upper pelvis, but resembled a primate in the lower portion with an oval canal (Lovejoy 2005). As a result, *A. afarensis* gave birth to babies that emerged sideways in order to fit through the birth canal (Fischman 1994). This birth process continued until a few million years ago, when bigger brains evolved.

When a larger fetal brain developed with the genus *Homo,* about 2.5 million years ago, the birthing process became more difficult (Rosenberg *et al.* 2007). Over those 2.5 million years, the human brain tripled in size, creating an incompatibility between the pelvis and fetal head (Schoenemann 2006). Natural selection would not have favored development of an even wider pelvis because that would spread the legs laterally which would compromise the efficiency of bipedalism (Fischman 1994). To accommodate a large fetal head, the lower end of the birth canal had to lengthen from front to back, which in turn caused the baby to rotate during delivery (Fig. 3). The human pelvis has become a tradeoff between bipedality and the passage of large-brained babies. The top of the human birth canal is widest from side to side, while the longest dimension of the baby's head is from the nose to the back of the head, causing the baby to enter the canal with its head oriented sideways. The canal shifts dimensions midway along its length, and the greatest length is from the front to back, requiring the baby to rotate 90 degrees to fit. The lower canal is widest in the front, which requires the baby to rotate again allowing it to emerge from the canal face down (Fig. 3). The twists and turns needed to navigate the birth canal have greatly increased the risk for damage and death for both the mother and baby. The exhaustion from obstructed childbirth made childbirth the leading cause of death among women of childbearing age 100 years ago (Ackerman 2006).

The large fetal brain not only favored selection for the alteration of the pelvic structure, it also changed the development requirements of the fetus (Rosenberg *et al.* 2007). Larger fetal brains require more oxygen during development which has caused the placenta to be deeply invasive. This has been linked to preeclampsia (only found in humans), which occurs in 10% of pregnancies, and is the leading cause of maternal mortality in developed countries. Preeclampsia is characterized by high blood pressure and protein in the urine of the pregnant woman after the 20th week of pregnancy (Preeclampsia 2012). Because of such problems during pregnancy and birth, many doctors are trying to avoid these issues by performing a Cesarean section, or C-section (Walrath 2003).

Walrath (2003) argues that obstetricians have funneled human births into a single "normal" category. If labor is not progressing at a certain rate, many doctors will diagnose an incompatibility with the head of the fetus and the pelvis of the mother (cephalopelvic disproportion) and suggest a C-section. It is also common for doctors to perform a C-section when severe preeclampsia is suspected to lessen the risk of mortality (Sibai *et al.* 2007). Despite the difficulties and risks associated with unassisted births, there are still many societies that choose such births and still manage to keep their populations stable (Walrath 2003). Modern medicine has increased the chances of both mother and fetal survival during birth, but have doctors become too reliant on medical procedures to determine a successful birth? Are humans setting themselves up to lose their abilities to deliver babies vaginally? Do humans rely too much on modern medicine to survive as a species?

SYNTHESIS

Evolution by natural selection leads to populations that are best suited to survive and reproduce in their environment. Humans were faced with an environment in which bipedalism increased survival and reproduction, so structural changes were made to adapt to their environment. As humans continued to evolve, certain features of bipedalism became restrictive. The previous sections reviewed how specific structural changes for bipedalism have caused different medical problems faced by modern humans. The anatomy of the human spine is an underlying cause of ailments like lower back pain, slipped or ruptured vertebral disks, and osteoporosis-related spinal fractures. The human pelvis requires a very complicated fetal delivery that puts both the mother and child at risk. Strong selective pressures favored a bipedal body, and thus humans have compromised certain aspects of their anatomy. These compromised features do not necessarily result in changes in the likelihood of survival or reproduction, the foundation of natural selection. Osteoporosis-related spinal fractures generally occur after reproductive ages, so they cannot be reduced by natural selection (Karasik 2008). Lower back pain, slipped/ruptured vertebral disks, and complicated childbirth certainly occur during reproductive years and can, therefore, be acted upon by natural selection. These ailments can, and have, caused a decrease in survival and reproductive success, so why do we still face these problems?

Evolution is the gradual change in the gene pool of a population over time, and for human evolution, the time frame is millions of years. Human ancestors began walking upright 6-7 million years ago, and obligatory bipedalism is believed to have occurred 3.2 million years ago (Ackerman 2006). Larger brains began developing only 2.5 million years ago with modern brain size only existing for less than 0.5 million years (Rosenberg *et al.* 2007; Schoenemann 2006). Humans have only had 500,000 years to adapt to bipedalism and larger brains, a small amount of time compared to the approximate 3 million years it took to develop obligate bipedalism. Besides the brief time since facing some of these problems, humans have also made major advances in the medical field that alleviate some of the selective pressures against them.

Having the ability to fix some of these problems allows those who might not have survived or reproduced to do just that. If those with lower back pain were unable to alleviate the pain or have surgery to fix the problems, they would be unable to move around as easily, significantly lowering their chances of survival and reproduction. Women who are unable to deliver their baby vaginally due to a cephalopelvic incompatibility would not survive nor reproduce. Over many generations, these traits may have been removed from the gene pool, but modern medicine allows many people to overcome such problems.

Humans are the only species that understand the process of evolution and are in a position to manipulate natural selection, as often seen in the breeding of plants and animals

(Chan 2008). Humans are the only species that are able to overcome certain selective pressures by medical intervention. Humans have the capabilities to influence their environment, which directly alters the course of natural selection. Modern medicine has enabled women who are unable to birth their children vaginally to give birth through Cesarean section, avoiding the pelvic problem all together. When the fetal brain became larger, it was limited in size because it still needed to fit through the birth canal (Rosenberg *et al.* 2007). This is why human babies are so dependent and helpless when they are born. Human babies are born with a brain that is only 27% the size of an adult brain, compared to other primates that are born with a brain 57% the size of an adult brain. The human fetus is delayed developmentally in the womb because it must fit through the birth canal, requiring excessive time for development out of the uterus in what is referred to by some as the "exterogestation" period (Rosenberg *et al.* 2007). The fit through the pelvis may be what is determining the size of the brain for humans, but if babies are able to bypass the pelvis, there may be an increase in brain size of future humans (Balter 2005). The ability to overcome certain pressures has the potential to change the course of natural selection because it is no longer the natural environment that provides the selective pressures but medical technology.

Medical advances have the potential to allow humans to override natural selection and dictate the selective pressures acting upon them. Medical technology relies greatly on economic resources, and these are limited throughout the world (Stock 2008). Most people that benefit from medicine live in developed countries with a strong healthcare system. Countries with the resources available to assist in medical problems are able to help their people better survive and reproduce. The Americas and Europe are considered developed regions of the world and maintain a healthcare system that provides care to the population. Africa, on the other hand, is not considered a developed region, and does not have the same level of healthcare. This is emphasized by the life expectancy of those regions. The Americas and Europe have a life expectancy from birth of 76 years, while Africa's life expectancy from birth is 56 (Life Expectancy 2011). The deaths due to communicable, maternal, perinatal, and nutrition further emphasized the influence of modern medicine across the regions (Table 1). In Africa, approximately 6.5 million people die annually from such medical complications, but Europe and the Americas experience significantly less mortalities from the same medical problems (Causes of Death 2008 Summary Table). The drastic differences in these trends are seen in the number of deaths due to respiratory infections, non-HIV sexually transmitted diseases, and obstructed labor (Table 1). In Africa, obstructed labor accounted for 8,796 deaths, while the Americas experienced 67 deaths and Europe had only 52 (Causes of Death 2008 Summary Table). In Africa, where medical technology is not as readily available, more women die due to cephalopelvic disproportion (the most common cause of obstructed labor) because they do not have access to the technology needed for a Cesarean section. Populations in developed countries with access to modern medicine have fewer deaths associated with treatable diseases, allowing them to survive fatal diseases and reproduce[1]. More people in Africa die from treatable diseases because of the limited access to modern medicine. Natural selection is acting upon the populations of this region because people are dying before they can reproduce. It is,

[1] It is interesting to note that developed regions of the world (the Americas and Europe) experience more deaths due to malignant neoplasms (cancer) than Africa, most likely due to the higher life expectancy since cancer incidence increases with age (Causes of Death 2008 Summary Table). Because they occur post-reproduction, they cannot be acted upon by natural selection.

therefore, no surprise that a modern example of natural selection comes out of Africa where healthcare is not as available.

Being a carrier for sickle cell anemia increases one's ability to survive malaria (Luzzatto 2012; Stock 2008; Balter 2005). A carrier has a heterozygous genotype, in which two different alleles for a gene are present, a dominant and recessive pair. A carrier is not affected by the disease but can pass the genes that code for the disease to their offspring. A carrier for sickle cell anemia has normal blood cells, but it does display some sickled blood cells (characteristic of sickle cell anemia) when oxygen levels are low (Luzzatto 2012). This is important for people who are exposed to malaria, a disease that can kill humans through contact with a mosquito infected with the *Plasmodium* parasite. Humans who are heterozygous for sickle cell anemia more easily survive the disease because of their cells' ability to sickle (Luzzatto 2012). When the parasite enters the blood cell of a sickle cell carrier, the blood cell sickles and is detected and destroyed by white blood cells, which in turn effectively kills the parasite and increases survival. This is why areas that are exposed to malaria, common throughout central Africa, have an increase in heterozygous genotypes for sickle cell anemia (Stock 2008). That particular genotype allows certain people to survive a disease that kills many people before they are able to reproduce, displaying the process of natural selection.

Modern medicine has enabled humans to overcome obstacles that have the potential to be deadly, in particular obstructed labor. It is possible that populations without access to medical procedures will select against anatomy that increases the risk of obstructed labor. Anatomy that results in obstructed labor, and thus death, will be selected against by natural selection. Over generations the anatomy could result in a less restricted birth canal, successfully overcoming this particular scar of human evolution. This process mimics the example of natural selection seen with malaria and sickle cell anemia. Selective pressures are much more intense in regions where medical treatment is not as available resulting in natural selection. However, populations in which advanced medical technology allows for intervention during obstructed labor lose the selective pressure against such anatomy. Women that may have died from labor are now able to survive and reproduce, passing on the genes for a restricted birth canal.

Humans have evolved to be obligate bipeds with anatomical modifications that place strain on certain features (particularly the pelvis and back). All humans share these flawed characteristics, but some more easily alleviate their restraints through access to modern medicine. Those without access to medical technology are more subject to the pressures of natural selection and have the potential to overcome these obstacles as a population. Humans with access to modern medicine partially eliminate these pressures making them ill adapted to their circumstances. Modern medicine is reducing the human's ability to adapt to their environment and allowing those with unfavorable traits to reproduce and pass on those traits.

As long as there are heritable differences and variable reproductive success, natural selection will always be working, regardless of medical advancements. Access to modern medicine seems to have decreased the role of natural selection in humans. Those that do not have access to the same medical technology are seen to show greater response to selective pressures from their environment. While there may have been some relaxation of selective pressures, energy sources are decreasing, the human population is increasing, and the climate is changing (Balter 2005). All of these factors could disrupt the availability of medicine to humans causing natural selection to, once again, have a large impact on human evolution.

CONCLUSION

With the evolution of obligatory bipedalism came structural changes that cause medical problems for modern humans. I highlighted changes to the spinal column and the pelvis which contribute to lower back pain, osteoporosis-related spinal fractures, and difficult and dangerous childbirth. While osteoporosis-related spinal fractures are unable to be selected against by natural selection, the other ailments are present during reproductive years and, therefore, have the potential to be acted upon by natural selection. Due to modern medical technologies, the selective pressures against these problems appear to have diminished. Survival and reproduction have come to rely heavily on, not only the medical technology, but, more importantly, the access to it. This suggests that the driving force behind modern human evolution is no longer strictly the natural environment, but the availability of medical resources. While there is still heritable differences and variability in reproductive success, there will be natural selection. It is just a matter that humans have the ability to manipulate their own reproductive success through modern medicine, and with it, their own evolution.

Region and Population	Obstructed Labor	Sexually Transmitted Diseases (Not HIV)	Respiratory Infections	Life Expectancy from birth
Africa (804,865,018)	1,151,063	42,246	8,796	56
Americas (915,430,096)	245,412	1,500	67	76
Europe (889,169,892)	219,748	1,050	52	76

Table 1.

Number of deaths due to specific communicable, maternal, perinatal, and nutritional illnesses in 2008 (Causes of Death 2008 Summary Tables and Life Expectancy 2011).

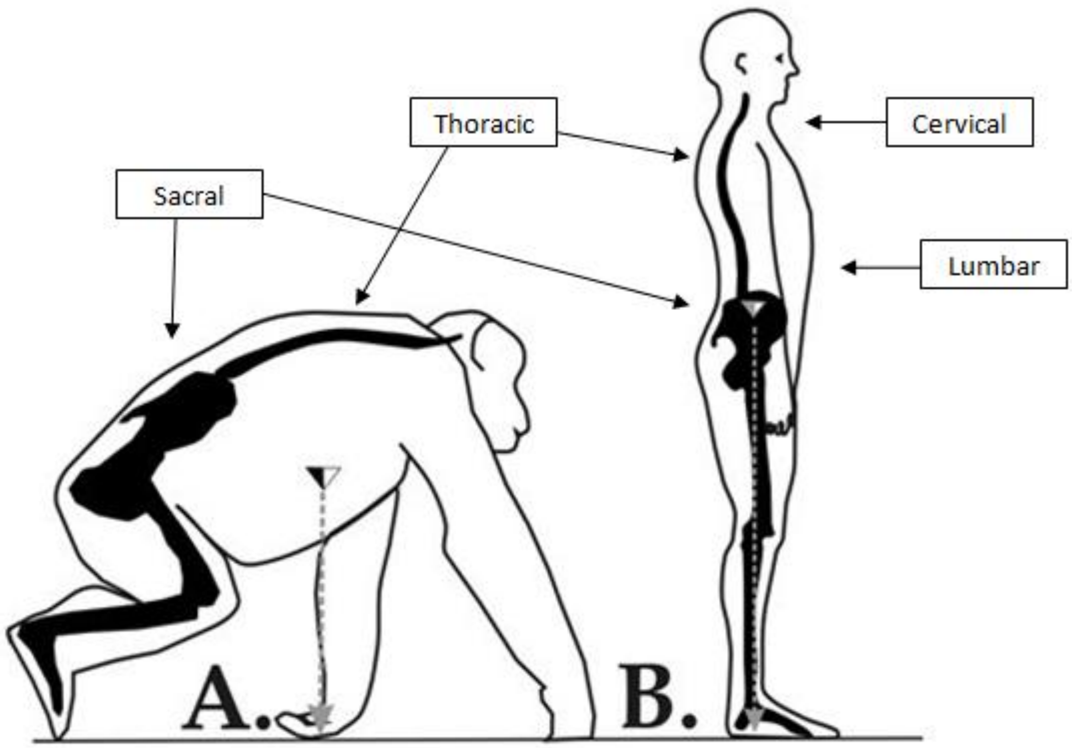

Figure 1.

(A) shows the orientation of the spine, pelvis, and center of gravity of a chimpanzee while (B) shows these traits in a human. Boxes label specific arches in the spinal column with humans having two additional arches (After Legaye 2011).

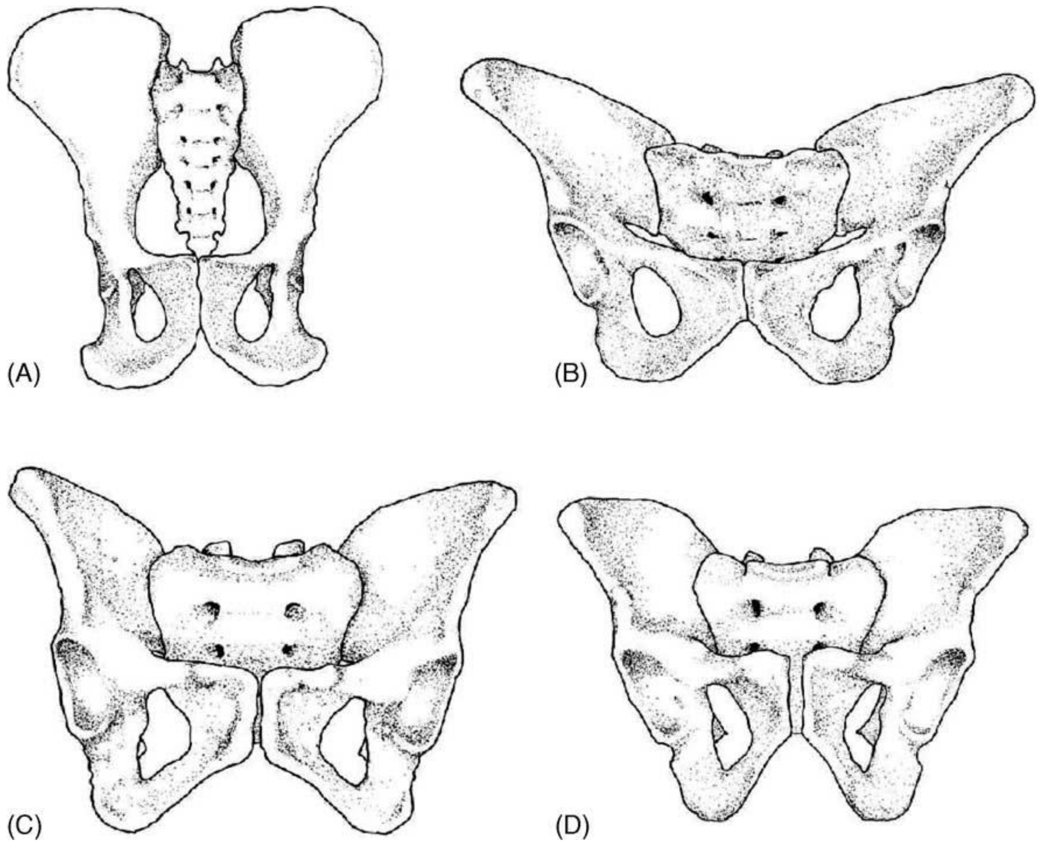

Figure 2.

Pelvis of (A) chimpanzee; (B) AL-288-1 (Australopithecine); (C) human female; (D) human male. (Lovejoy 2005).

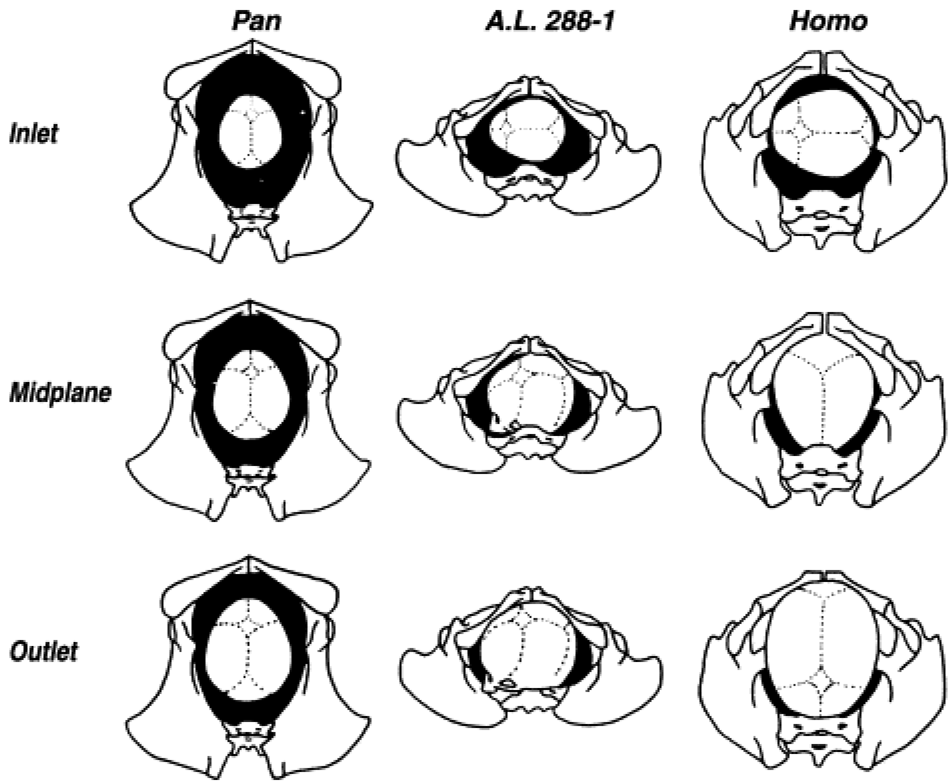

Figure 3.

View of birth process from an obstetrician's point of view of a chimpanzee (Pan), an Australopithecine (A.L 288-1), and a human (Homo). (Rosenberg *et al.* 2006).

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