The Physical, Physiological, and Biocultural Evolution of Birth

Ant 570—Physical Anthropology

11/19/02

Text pages: 17

Bibliography Pages: 2

Figure Pages: 4

Introduction

Physical anthropology concerns itself with the study of human evolution, variation, and adaptation of extant and extinct populations. Evolution can be viewed in terms of a species' success rate, through an individual's survival to the reproductive age, and the subsequent reproduction and production of fertile offspring. The birth process can be seen as a culmination of these evolutionary requirements. It is possible to consider the costs and benefits of physiological and biocultural factors when considering the influential nature of the birth event. Some survival and reproduction studies lead to the examination of birth as an evolutionary event. Any adaptations that enhance reproductive success, even if they involve compromises on an individual or species level, can be seen as advantageous to a species (Trevathan, 1987).

Purpose and Methods

The purpose of this paper is to investigate the evolution of human birth in terms of the physical, physiological, and biocultural factors that have interacted over time, comparing *Pan tryglodytes* to *Homo sapiens.* An evolutionary framework can clarify the physical data concerning pelvic morphology and encephalization in relation to the emergence of bipedalism. An understanding of the relevant physiological changes complements the morphological data, with topics such as helplessness of the young (altriciality), the existence of a hemochorial placenta, and gestational length. These physical and physiological changes such as encephalization, pelvic morphology, and the altriciality of the newborn determined in part the biocultural evolution of birth, including activities such as mother-infant bonding and social support from social group members. A convenient method for acquiring data for an evolutionary model has come from studies using the extant chimpanzee (Videan et al., 2002; Trevathan, 1987; Rosenburg and Trevathan, 2001).

A critical literature review and discussion concerning the chimpanzee and modern humans serve to introduce sufficient evidence in order to accomplish the purpose of this paper.

Pelvic Morphology and Encephalization

Trevathan (1993) sets the date of the appearance of bipedal locomotion as five million years ago, in the *Australopithecus* genus. This adaptive locomotive trait created important changes in pelvic morphology, which in turn created new challenges in parturition. Increased encephalization started approximately two million years ago, and characterizes the genus *Homo*. Combined with the changes in pelvic morphology, the increased fetal cranial size created even more problems in the birth process for *Homo* females (Trevathan, 1993).

Bipedalism and Pelvic Morphology

Pelvic morphology is a diagnostic element in determining the locomotive means of a species (Marchal, 2000). Specifically, bipedalism can be determined by looking at the morphological characteristics of the pelvis. *Homo* and *Australopithecine* pelvic morphology indicate bipedalism (although different kinds), while chimp pelves indicate the possibility of bipedalism, but not as an exclusive means of transportation [see figure 1]. The pelvis of the *Australopithecus* is more like that of humans than chimps (Boyd and Silk, 1997). The blade of the illium is longer and wider in chimpanzees than in *Australopithecus* or *Homo*. This obvious difference is due to the functions of the pelvis in each species' body, i.e. whether the pelvis is used to support the weight of the body.

Figure 1: Chimp, *Australopithecus*, and Human Pelves.
(University of Texas, 2001).

The *Australopithecus* genus is hypothesized to have the capability for bipedalism, but only in certain conditions, such as carrying food. Videan et al. (2002) showed that chimps can be seen using bipedal locomotion to carry food in captive situations. These chimps were bipedal only occasionally when presented with the opportunity to watch for predators or forage for food. This study may present some explanations as to what activities resulted in *Australopithecus* being bipedal, if only for particular activities or environments. Humans, on the other hand, are habitual bipeds, unable to transport themselves quadrupedaly without extreme effort.

The body weight of chimps is more equally distributed in the hindlimbs and forelimbs, and the innominate morphology reflects a limited reliance upon the pelvis for bipedal weight bearing purposes. Lying parallel and lateral to the spine is the illium, the blade of which flares outward. The ischium also extends back towards the rear of the chimp. The chimp fetal head passes by the last three sacral vertebrate, which are bonded to each other above the pubic symphysis (Trevathan, 1987).

The changes in morphology that resulted from selection for bipedalism included a readjustment of the pelvis and changes in the major locomotive muscle attachments. Habitual bipedalism necessitated a reduction in the gap between the sacroiliac joint and acetabulum (hip joint), with a reduced sagittal (side to side) breadth. This morphological change caused a limited pelvic aperture, and constraint on the size of the fetal head was a result. (Trevathan, 1987).

Concerning body weight distribution, bipeds need a more rigid and upright positioning of the pelvis. Over half of the body weight is supported by the pelvis and is made possible by a smaller length, but broader breadth, of the illium. It also has more anterior to posterior coverage within the human body, creating a bowl-type effect for the organs and spine to sit upon. The sacroiliac joint is longer and sturdier, and the ischium is stockier and smaller. These morphological characteristics provide a solid center of balance and weight support in bipedal humans. The connection point for the pubis is directly across from the sacrum in humans. Therefore, an even smaller pelvic passageway is navigated by the fetal cranium [see figure 2] during birth (Trevathan, 1987).

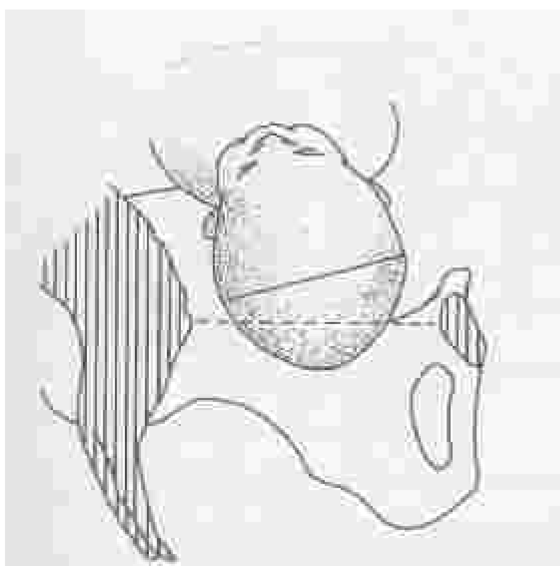

Figure 2: Lateral view of human passage through pelvis. (Trevathan, 1987)

Relethford (2003) puts these changes of morphology in an evolutionary perspective, indicating that these transformations in shape, position, and function were relatively minor anatomical changes. However, the cumulative effect of these readjustments was phenomenal when considering the phylogenetic lineage of the hominids.

The Cranium and Birth

It is clear now that the locomotive and postural traits—evident in pelvic morphology—have limited the size of the pelvic inlet and outlet, birth canal, and subsequent fetal head size at the time of birth. The orientation of the cranium at the time of birth differs in chimps and humans. The sagittal (side to side) plane of the pelvis is greater in chimps, with the transverse plane of the chimp pelvis being smaller. The size of the chimp fetal head corresponds to the openings in the pelvis (Trevathan, 1987).

There is a difference in the pelvic inlet and outlet dimensions in humans, however. Rosenburg and Trevathan (2001) explain the changes in the cross-sectional measurements of the birth canal through the pelvic aperture. The human fetal head is described as an oval, with the longest measurements made between the front to the back of the head. Trevathan (1987) states the entrance of the birth canal—the pelvic inlet—is widest in the transverse dimension, with the exit of the birth canal—the pelvic outlet—widest in the sagittal plane. Since the oval cross-section changes width halfway through the birth canal, a rotation of the fetal head and shoulders is necessary during birth. The head faces the mother's side first and then turns to the back, returning to the side slightly again as the cranium exits the birth canal. The last rotation situates the shoulders of the infant into the appropriate position for birthing, with the infant facing away from the mother [see figure 3] upon exiting (occipital anterior position). Since the oval cross-section of the birth canal does not change in chimps, an easier birth is present in the species, with the chimp infant facing the mother upon exiting the birth canal (occipital posterior position), allowing for the use of the mother's hands to aid the process (Rosenburg and Trevathan, 2001).

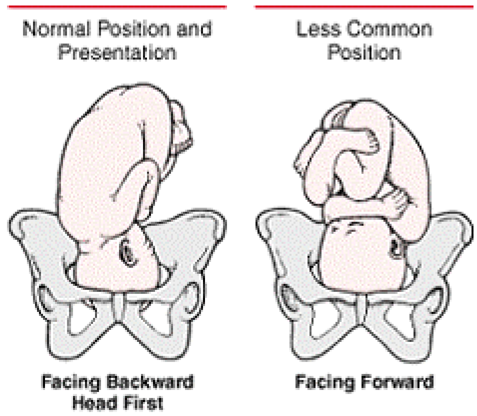

Figure 3: Occipital anterior position and occipital posterior position. (Merck, 2002).

There is less need for a chimp to rotate in the birth canal as the size of the head and pelvic inlet are relatively well-matched. Chimps have been observed as experiencing considerable pain during childbirth, but with most births lasting less than one half hour (Trevathan, 1987).

Physical Problems with Birth

Trevathan (1993) discusses the occipital anterior position in human birth as being one of the major changes in human parturition that took place after the emergence of bipedalism. This fetal position results in the mother's inability to use her hands to assist in labor. To do so could risk injury to the fetus' neck or spine (Trevathan, 1987). Also, the occipital anterior position may lead to the difficulty of the mother in clearing the neonatal breathing passages, the nose and mouth, during birth. The author hypothesizes that these challenges may be one of the reasons assisted birth evolved, and that this practice appeared in the *Homo* genus when encephalization became a major evolutionary trend—two million years ago. The increase in cranial size and presumably, resultant mental function, is likely to have something to do with how much fear the mother feels, based on her increased awareness of her self, her body, and its pain during labor and birth. The author states that fear would be the major stimulus for seeking help (Trevathan, 1993) **Punctuation Problem**

An increasing number of birth canal obstructions such as the one illustrated in figure 4 shows a breech presentation of a fetus in the birth canal. This photograph is of a young adult modern female ca. 1100 AD, with the right humerus of the fetus is visible in the birth canal. The movements of the fetus often become restricted at the end of gestation, and the final position of the fetus at the onset of labor is oftentimes the birthing position. If a fetus is rotated the wrong way, obstruction of the birth canal can result [also see figure 5 for depictions of breech presentation].

Figure 4: An obstructed birth canal.
(Aufderheide AC & C Rodriguez-Martin, 1998)

If the cephalopelvic ratio is high, the pelvis is ill-formed, or if the fetal position at the onset of labor is abnormal, a breech birth may occur. These complications may have evolved along with the pelvic morphological and encephalization changes associated with bipedalism. Obviously the benefits of bipedalism outweighed the costs associated with this change, as humans have remained bipedal throughout evolution (Trevathan, 1987).

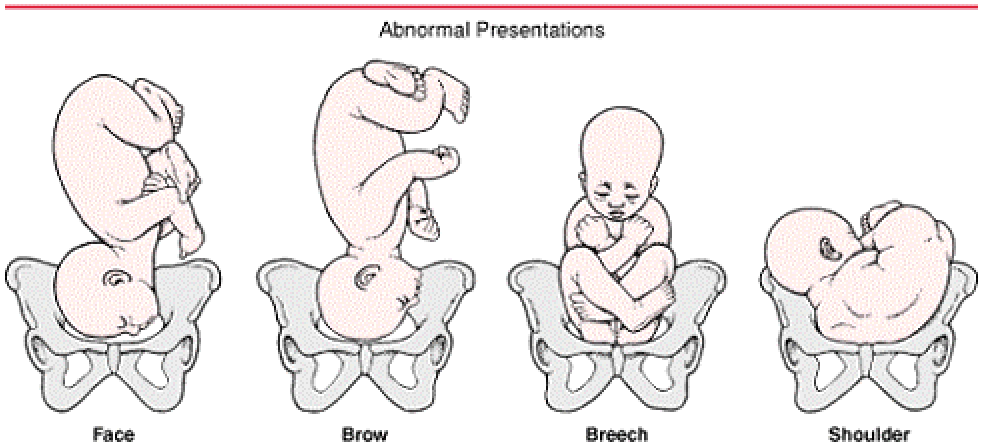

Figure 5: Breech presentations. (Merck, 2002).

Encephalization and Development

The evolutionary outline based on Trevathan's work (1987)**Punctuation Problem** , presents the pressures of encephalization as conflicting with the pelvic morphology that was suited to bipedalism. Encephalization would result in an increasingly difficult birthing process, and eventually would have been subject to limitations regarding how much the mother could pass through her birth canal, probably occurring around two million years ago. Because the upper limit on birth canal expansion had been reached after bipedalism emerged, the compensation for encephalization was to alter the growth and development patterns of the fetus and infant. That is, the fetal cranium could grow only so much in the uterus of the mother, with much more of the development of the neonatal brain taking place after parturition (Trevathan, 1987). Infant monkeys are born with a brain that is 65% developed, while infant chimps' brains have 40% of the total development. Human infants are born with a brain that is only 25% completed in it developmental processes (Trevathan, 1993). These data contrast with evidence of neonatal development after parturition in chimpanzees. On a scale of an infant's developmental maturity at birth, chimps fall between monkeys and humans (Trevathan, 1987).

Evidence for this altriciality of human offspring is found in the nutritional content of the mother's milk. The relatively low nutritional content of the milk demonstrates that a constant contact with the breast was necessary in order to support the infant. The nutrient composition of the breast milk of other primates is comparable to that of humans. Trevathan (1987) presents the milk of human mothers to have 6.5% carbohydrates, 1.3% protein, 4.0 % fat, with the remaining 88.2% being water. The chimp mother's breast milk contains 7.0% carbohydrates, 1.2% protein, 3.7% fat, with the remainder (88.1%) being water. Other (nonprimate) species, such as the lion, which can leave its young for 6-8 hours at a time in search of food, has milk with protein content as high as 12.5%, and a fat content of 18.9%. With the relatively low nutrient content of the breast milk of primates, bipedalism in humans allowed the infant to be carried by (or strapped to) the mother while searching for food. Chimps can cling to their mothers with the help of the divergent toe and body hair to grasp. Human mothers who could search for food while keeping their hungry infant close to the breast were selected for over time (Trevathan, 1987).

Physiological Evolution of Birth

During pregnancy, a woman's body functions to maintain the health of the fetus. Different physiological changes have taken place over time, in primates and non-primates, that have resulted in different costs and benefits to the mother and fetus. One of the important physiological aspects of a human female's reproductive system is the hemochorial placenta, which evolved in animals around forty million years ago, distinguishing the suborder of Haplorhines (Trevathan, 1987).

The Hemochorial Placenta: Benefits and Risks

The hemochorial placenta functions as a fetal vascular organ, providing an effective means of transporting oxygen to the developing fetus. The placenta also functions to shield the fetus from harmful substances, bacteria for example. However, the close relationship of the two physiological systems—mother and fetus, compared to other placental species where there is more separation between the two, can result in higher levels of abortion in humans (Trevathan, 1987).

Although the actual blood of the mother and fetus is not shared, the mother's antibodies against the fetus can be passed through the membranes in a number of blood-related incompatibilities such as Rhesus incompatibility and ABO incompatibility (Relethford, 2003). A fetus could theoretically be rejected due to the maternal antibodies attacking the fetus. The fetus can share less than 50% of the mother's genes, because of the recessive genes that may be inherited. This provides a reason for why the mother's body would chose to attack her own offspring (Trevathan, 1987). Bottini et al. (2001) use the Hardy-Weinberg Principle to examine the ABO blood groups and determine that, in one blood type situation (Mother type A, Father and Child type B), an antigen against the B blood type, the mother's A blood type, or the fetus' B blood type could in fact protect the fetus from recurrent spontaneous abortion.

Gestational Time

The gestational time of the infant, another physiological factor in the evolution of birth, seems to have a direct relationship with the cranial size of the fetus. Limitations on cranial size may determine when labor begins, when the uterus cannot tolerate any more cranial growth. A longer gestational time is characteristic of animals with higher cranial capacity, with as much brain development as possible happening in the uterus. The increased encephalization of humans is evident from the data that suggest that infants reach a stage of development that other primates exhibit shortly after birth, only at the human postnatal age of six to nine months (Trevathan, 1987). Pike (2001) reports on the gestational time of great apes as being 228-264 days, with human gestational time (for those humans with larger brains) being 267 days. The infant continues to mature after birth, but only with sufficient resources and effort on the mother's part, such as lactation and transportation of the infant. For example, the cranial bones of the infant, flexible and unfused at birth, contrast with those of chimpanzees, which are rigid enough to support the strong chewing muscles once the chimp is weaned (Trevathan, 1987).

Stress and Parturition

An ecological model proposed by Pike (2001) inquires as to what the stress level and nutritional status of the mother is at the onset of labor, tying these factors into the gestational time and survival rate of the offspring. She states that parturition is the result of a complex network of physical, biochemical, and hormonal messages that are influenced by environmental stress. Specifically the corticotrophin releasing hormone (C-RH) controls the rate of development, but also when a woman births her baby. The source of C-RH is the placenta, and levels increase dramatically after approximately 17 weeks of gestation. If a fetus is suffering from hypoxia or malnutrition, for example, the multi-functional stress release protein (C-RH) levels will increase, stimulating parturition. At the present time there are no significant findings concerning how C-RH levels function in pregnant women cross-culturally (Pike, 2001).

Biocultural Evolution of Birth

The survival of the offspring may depend on more than just the physical and physiological capabilities of the mother. Complications resulting from a "mismatch" of maternal and fetal traits—a high cephalopelvic ratio, for example—may have caused the evolution of biocultural factors such as assisted birth and the bonding of the mother and infant. The fear of obstruction, the inability to manipulate the fetus with the hands—due to the occipital anterior birthing position—and the altriciality (helplessness) of the newborn may have caused a selection for assistance at the birth event. Encephalization and obligate midwifery are explained by Trevathan (1987) as evolving concomitantly.

Assisted Birth

While chimpanzee mothers have been observed as removing themselves from the social group during the time before parturition, humans establish a social network before the onset of labor to aid them (Trevathan, 1987). The relative ease of chimp births does not necessitate any help from other group members, and the occipital posterior birthing position allows for the mother to clear the air passageways of the newborn with her own hands. (Rosenburg and Trevathan., 2001). However, mortality is reduced when emotional and physical support is given to the human mother during birth. Rosenburg and Trevathan (2001:68) speak of the "triple challenge of big-brained infants, a pelvis designed for walking upright, and a rotational delivery…[where midwife assistance] compensated for these difficulties."

If mortality of the mother does occur, her genes may survive yet with the presence of a birth assistant at the time of death. Trevathan (1987) discusses how witnesses of a birth find themselves bonded to the mother's infant, with an urge to take care of the newborn if the mother happens to die. Again, although the assistants may provide only minimal emotional support to the laboring mother, even a small decrease in mortality would increase the selection of seeking out others during the birth event (Trevathan, 1993). If a pregnant woman chooses a kinswoman as her birth assistant, then some degree of security can be afforded to her regarding the survival of her child if she were to die. Kinship studies have shown that there is much variability in the role of surrogate mother, or who one considers their family to be. In the Trobriander's eyes, a mother contributes nothing to her child, she just houses the infant until it is born. Recent dilemmas over who is the "real" mother of a child: the egg donor or the egg host—have erupted into million dollar lawsuits in Western society. These cross cultural data strengthen the argument that it is partly the social relationships, not just the genetic relationships, that can determine who you consider "mother" to be (Holy, 1996).

Birth in Western Society

Just as surrogate mother-hood and support systems are cultural constructions, so too is the more modern and technocratic model of birth in industrialized societies. Davis-Floyd (1992) presents a convincing argument detailing the characteristics of this model, and its results on mothers and children in society. A male dominated, body-as-machine, doctor-as-technician model inherent in many Western societies has resulted in increased feelings of helplessness, identity crisis, and body image distortion. When women's Cesearean sections, most of which are unnecessary, are scheduled around the doctor's social schedule, women do not feel that the health of their children and themselves are the priority of the biomedical system. Isolation in delivery rooms has been common during this major surgical procedure, as well as the separation of the mother and child post-partum. Trevathan (1993) advocates a simple answer of just waiting longer when the gestational time runs over the approximate due date; unless of course a significant health threat is perceived.

Bonding after Birth

The bonding of the mother and the infant has been the subject of numerous studies. A critical bonding period occurs in the first hour after birth, with extensive eye contact, touching, cooing or shushing, attempts at feeding, and eventually, sleep of the mother and infant. The child's survival depends in part on the mother's willingness to care for the infant, and bonding has served as an evolutionary mechanism to support the child's survival. The mother's survival is actually compromised by having her offspring introduced into the social group (with evidence of the birth and crying of the infant possibly attracting predators), so the bonding promotes her survival as well. Shushing and nursing are two ways to quiet a child that may pose a threat to the social group (Trevathan, 1987).

Trevathan (1987) believes that there is a critical bonding period between infants and mothers, and numerous physical benefits to the child and mother are the result. The hormonal endorphins released during parturition benefit the respiratory system of the infant, as well as the emotional and psychological state of the mother after the stressful birth event. The proximity to the newborn (and nursing behaviors specifically), while providing warmth and sustenance to the infant, promote contractions for the expulsion of the placenta due to the release of oxytocin into the mother's bloodstream. The risks of hemorrhage are reduced in the infant due to the Vitamin K ingested from the mother's milk. Drugs given to women who wanted to attain pain-free childbirth have been found to dull the senses of the mother and child during this critical bonding period (Trevathan, 1993).

Davis-Floyd (1992) points out another possible benefit to the infant, the introduction of positive maternal bacteria during the bonding period—which takes place 30-60 minutes after birth. If an infant is removed from the mother, other clinical bacteria may instead infect the newborn. Since there are many medical procedures that can compensate for any lacking element in this critical period—such as mechanical heaters when it is cold instead of a mother's skin, radio music instead of mother's voice—the bonding between mother and infant can be seen as a thing of the past where survival of an infant is no longer dependent solely on the mother. In this evolutionary perspective, it is obvious given the physical, physiological, and biocultural traits that the bonding of mothers and infants must have been selected for in order to optimize survival.

Discussion and Conclusion

This review of the physical, physiological and biocultural factors that have contributed to the evolution of birth is only a partial representation of the topics concerning the subject. By no means is this a complete evaluation, but the methods and topics used here to provide a preliminary synthesis of relevant topics. Some limitations for the reader to consider are the lack of empirical data concerning the sizes of chimp and human crania and pelves.

In terms of physical evolution of hominids, the pelvic morphology and encephalization acted as competing forces. Although we can never truly measure the evolutionary relationship between these two factors, infant and adult crania and pelves from chimpanzee and human osteological samples can be analyzed. Some aspects of the neonatal condition can be determined by examining the nutrients gained from the lactation of the mother.

The physiological evolution of the placenta and gestational length of the pregnancy provide information regarding maternal-fetal incompatibility, as well as the cranial capacity and morphology of the neonate. The developmental processes of the fetus have changed due to the emergence of bipedalism. A continuation of physical, physiological, psychological, and emotional development is evident in the postnatal phase, more so than in chimpanzees or any other extant species. Stress has been found to affect the gestational time of the fetus.

The biocultural aspects of birth including assistance at birth and a critical bonding period can be viewed in an evolutionary light, illuminating both the costs and benefits to the mother, the infant, and the social group supporting the new pair. A possible reason for the introduction of assistance at birth is the bipedal locomotion and later encephalization that characterizes hominids. The restrictions of the birth canal and cranial diameters resulted in a more complicated birthing process for our species.

Bonding in the mother and newborn, although not universally practiced, can be understood as promoting the survival of the species, both on an individual and group level. An interdependency of the three parties develops over time—down to the family unit level that our society is familiar with today. The benefits of hormonal exchanges between the mother and infant indicate that close contact after the birth was favored, even though recent technocratic models suggest otherwise.

In short, the success of parturition is the fundamental unit of evolution. Positive birth outcomes encompass the survival of the mother to a reproductive age, and the traits from that achievement are passed to the offspring. In future research, the study of the adaptations that promote successful reproduction should therefore be considered a worthwhile undertaking in attempting to understand human evolution.

References

Aufderheide AC **Format References** & C Rodriguez-Martin (eds.). 1998. The Cambridge Encyclopedia of Paleopathology. Cambridge: Cambridge University Press.

Bottini N, GF Meloni, A Finocchi, G Ruggiu, A Amante, T Meloni, and E Bottini. 2001. Maternal-fetal interaction in the ABO system: A comparative analysis of healthy mothers and couples with recurrent spontaneous abortion suggests a protective effect of B incompatibility. Human Biology, 73:167-174.

Boyd R and JB Silk. 1997. How Humans Evolved. New York: W.W. Norton & Company, Inc.

Davis-Floyd RE. 1992. Birth as an American Rite of Passage. Berkeley: University of California Press.

Holy L. 1996. Anthropological Perspectives on Kinship. Chicago: Pluto Press.

Marchal F. 2000. A new morphometric analysis of hominid pelvic bone. Journal of Human Evolution, 38:347-365.

Merck Manual of Medical Information—Home Edition, Section 22—Women's Health Issues, Chapter 249: Illustration of Position and Presentation of the Fetus. 2002. Whitehouse Station, NJ. Revised 2002. http://www.merck.com/pubs/mmanual_home/illus/249i1.htm

Pike IL. 2001. The evolutionary and ecological context of human pregnancy. In Ellison PT, editor, Reproductive Ecology and Human Evolution. New York, Aldine de Gruyter Press. p. 39-58.

Relethford JH. 2003. The human species: An introduction to biological anthropology. New York: McGraw Hill.

Rosenburg KR and W Trevathan. 2001. The evolution of human birth. Scientific American, 285:72-78.

Trevathan, WR. 1987. Human Birth: An Evolutionary Perspective. New York: Aldine de Gruyter.

University of Texas at Austin Human Biology 304 Spring 1998 Individual Project Page. 1998. Austin. Revised 12/26/01. Accessed 11/15/02. http://www.utexas.edu/courses/mcmurry/spring98/13/moya.htm.

Videan EN and WC McGrew. 2002. Bipedality in Chimpanzee (pan tryglodytes) and Bonobo (pan paniscus): Testing Hypotheses on the Evolution of Bipedalism. American Journal of Physical Anthropology, 118:184-189.