The evolution of human birth.

by Karen R. Rosenberg and Wenda R. Trevathan

The difficulties of childbirth have probably challenged humans and their ancestors for millions of years--which means that the modern custom of seeking assistance during delivery may have similarly ancient roots

GIVING BIRTH IN THE TREETOPS is not the normal human way of doing things, but that is exactly what Sophia Pedro was forced to do during the height of the floods that ravaged southern Mozambique in March 2000. Pedro had survived for four days perched high above the raging floodwaters that killed more than 700 people in the region. The day after her delivery, television broadcast and newspapers all over the world featured images of Pedro and her newborn child being plucked from the tree during a dramatic helicopter rescus.

Treetop delivery rooms are unusual for humans but not for other primate species. For millions of years, primates have secluded themselves in treetops or bushes to give birth. Human beings are the only primate species that regularly seeks assistance during labor and delivery. So when and why did our female ancestors abandon their unassisted and solitary habit? The answers lie in the difficult and risky nature of human birth.

Many women know from experience that pushing a baby through the birth canal is no easy task. It's the price we pay for our large brains and intelligence: humans have exceptionally big heads relative to the size of their bodies. Those who have delved deeper into the subject know that the opening in the human pelvis through which the baby must pass is limited in size by our upright posture. But only recently have anthropologists begun to realize that the complex twists and turns that human babies make as they travel through the birth canal have troubled humans and their ancestors for at least 100,000 years. Fossil clues also indicate that anatomy, not just our social nature, has led human mothers--in contrast to our closest primate relatives and almost all other mammals--to ask for help during childbirth. Indeed, this practice of seeking assistance may have been in place when the earliest members of our genus, Homo, emerged and may possibly date back to five million years ago, when our ancestors first began to walk upright on a regular basis.

Tight Squeeze

TO TEST OUR THEORY that the practice of assisted birth may have been around for millennia, we considered first what scientists know about the way a primate baby fits through the mother's birth canal. Viewed from above, the infant's head is basically an oval, longest from the forehead to the back of the head and narrowest from ear to ear. Conveniently, the birth canal--the bony opening in the pelvis through which the baby must travel to get from the uterus to the outside world--is also an oval shape. The challenge of birth for many primates is that the size of the infant's head is close to the size of that opening.

For humans, this tight squeeze is complicated by the birth canal's not being a constant shape in cross section. The entrance of the birth canal, where the baby begins its journey, is widest from side to side relative to the mother's body. Midway through, however, this orientation shifts 90 degrees, and the long axis of the oval extends from the front of the mother's body to her back. This means that the human infant must negotiate a series of turns as it works its way through the birth canal so that the two parts of its body with the largest dimensions--the head and the shoulders--are always aligned with the largest dimension of the birth canal [see illustration at right].

To understand the birth process from the mother's point of view, imagine you are about to give birth. The baby is most likely upside down, facing your side, when its head enters the birth canal. Midway through the canal, however, it must turn to face your back, and the back of its head is pressed against your pubic bones. At that time, its shoulders are oriented side to side. When the baby exits your body, it is still facing backward, but it will turn its head slightly to the side. This rotation helps to turn the baby's shoulders so that they can also fir between your pubic bones and tailbone. To appreciate the close correspondence of the maternal and fetal dimensions, consider that the average pelvic opening in human females is 13 centimeters at its largest diameter and 10 centimeters at its smallest. The average infant head is 10 centimeters from front to back, and the shoulders are 12 centimeters across. This journey through a passageway of changing cross-sectional shape makes human birth difficult and ris ky for the vast majority of mothers and babies.

If we retreat far enough back along the family tree of human ancestors, we would eventually reach a point where birth was nor so difficult. Although humans are more closely related to apes genetically, monkeys may present a better model for birth in prehuman primates. One line of reasoning to support this assertion is as follows: Of the primate fossils discovered from the time before the first known hominids, one possible remote ancestor is Proconsul, a primate fossil dated to about 25 million years ago. This tailless creature probably looked like an ape, but its skeleton suggests that it moved more like a monkey. Its pelvis, too, was more monkeylike. The heads of modern

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monkey infants are typically about 98 percent the diameter of the mother's birth canal--a situation more comparable with that of humans than that of chimps, whose birth canals are relatively spacious.

Despite the monkey infant's tight squeeze, its entrance into the world is less challenging than that of a human baby. In contrast to the twisted birth canal of modern humans, monkeys' birth canals maintain the same cross-sectional shape from entrance to exit. The longest diameter of this oval shape is oriented front to back, and the broadest part of the oval is against the mother's back. A monkey infant enters the birth canal headfirst, with the broad back of its skull against the roomy back of the mother's pelvis and tailbone. That means the baby monkey emerges from the birth canal face forward--in other words, facing the same direction as the mother.

Firsthand observations of monkey deliveries have revealed a great advantage in babies' being born facing forward. Monkeys give birth squatting on their hind legs or crouching on all fours. As the infant is born, the mother reaches down to guide it our of the birth canal and toward her nipples. In many cases, she also wipes mucus from the baby's mouth and nose to aid its breathing. Infants are strong enough at birth to take part in their own deliveries. Once their hands are free, they can grab their mother's body and pull themselves out.

If human babies were also born face forward, their mothers would have a much easier time. Instead the evolutionary modifications of the human pelvis that enabled hominids to walk upright necessitate that most infants exit the birth canal with the back of their heads against the pubic bones, facing in the opposite direction as the mother (in a position obstetricians call "occiput anterior"). For this reason, it is difficult for the laboring human mother--whether squatting, sitting, or lying on her back--to reach down and guide the baby as it emerges. This configuration also greatly inhibits the mother's ability to clear a breathing passage for the infant, to remove the umbilical cord from around its neck or even to lift the baby up to her breast. If she tries to accelerate the delivery by grabbing the baby and guiding it from the birth canal, she risks bending its back awkwardly against the natural curve of its spine. Pulling on a newborn at this angle risks injury to its spinal cord, nerves and muscles.

For contemporary humans, the response to these challenges is to seek assistance during labor and delivery. Whether a technology-oriented professional, a lay midwife or a family member who is familiar with the birth process, the assistant can help the human mother do all the things the monkey mother does by herself. The assistant can also compensate for the limited motor abilities of the relatively helpless human infant. The advantages of even simple forms of assistance have reduced maternal and infant mortality throughout history.

Assisted Birth

OF COURSE, OUR ANCESTORS and even women today can and do give birth alone successfully. Many fictional accounts portray stalwart peasant women giving birth alone in the fields, perhaps most famously in the novel The Good Earth, by Pearl S. Buck. Such images give the impression that delivering babies is easy. But anthropologists who have studied childbirth in cultures around the world report that these perceptions are highly romanticized and that human birth is seldom easy and rarely unattended. Today virtually all women in all societies seek assistance at delivery. Even among the !Kung of southern Africa's Kalahari Desert--who are well known for viewing solitary birth as a cultural ideal--women do not usually manage to give birth alone until they have delivered several babies at which mothers, sisters or other women are present. So, though rare exceptions do exist, assisted birth comes close to being a universal custom in human cultures [see box on next page].

Knowing this--and believing that this practice is driven by the difficulty and risk that accompany human birth--we began to think that midwifery is not unique to contemporary humans but instead has its roots deep in our ancestry. Our analysis of the birth process throughout human evolution has led us to suggest that the practice of midwifery might have appeared as early as five million years ago, when bipedalism constricted the size and shape of the pelvis and birth canal.

A behavior pattern as complex as midwifery obviously does not fossilize, but pelvic bones do. The tight fit between the infant's head and the mother's birth canal in humans means that the mechanism of birth can be reconstructed if we know the relative sizes of each. Pelvic anatomy is now fairly well known from most time periods in the human fossil record, and we can estimate infant brain and skull size based on our extensive knowledge of adult skull sizes. (The delicate skulls of infants are not commonly found preserved until the point when humans began to bury their dead about 100,000 years ago.) Knowing the size and shape of the skulls and pelvises has also helped us and other researchers to understand whether infants were born facing forward or backward relative to their mothers--in turn revealing how challenging the birth might have been.

Walking on Two Legs

IN MODERN HUMANS, both bipedalism and enlarged

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brains constrain birth in important ways, but the first fundamental shift away from a nonhuman primate way of birth came about because of bipedalism alone. This unique way of walking appeared in early human ancestors of the genus Australopithecus at least four million years ago [see "Evolution of Human Walking," by C. Owen Lovejoy; SCIENTIFIC AMERICAN, November 1988]. Despite their upright posture, australopithecines typically stood no more than four feet tall, and their brains were not much bigger than those of living chimpanzees. Recent evidence has called into question which of the several australopithecine species were part of the lineage that led to Homo. Understanding the way any of them gave birth is still important, however, because walking on two legs would have constricted the maximum size of the pelvis and birth canal in similar ways among related species.

The anatomy of the female pelvis from this time period is well known from two complete fossils. Anthropologists unearthed the first (known as Sts 14 and presumed to be 2.5 million years old) in Sterkfontein, a site in the Transvaal region of South Africa. The second is best known as Lucy, a fossil discovered in the Hadar region of Ethiopia and dated at just over three million years old. Based on these specimens and on estimates of newborns' head size, C. Owen Lovejoy of Kent State University and Robert G. Tague of Louisiana State University concluded in the mid-1980s that birth in early hominids was unlike that known for any living species of primate.

The shape of the australopithecine birth canal is a flattened oval with the greatest dimension from side to side at both the entrance and exit. This shape appears to require a birth pattern different from that of monkeys, apes or modern humans. The head would not have rotated within the birth canal, but we think that in order for the shoulders to fir through, the baby might have had to turn its head once it emerged. In other words, if the baby's head entered the birth canal facing the side of the mother's body, its shoulders would have been oriented in a line from the mother's belly to her back. This starting position would have meant that the shoulders probably also had to turn sideways to squeeze through the birth canal.

This simple rotation could have introduced a kind of difficulty in australopithecine deliveries that no other known primate species had ever experienced. Depending on which way the baby's shoulders turned, its head could have exited the birth canal facing either forward or backward relative to the mother. Because the australopithecine birth canal is a symmetrical opening of unchanging shape, the baby could have just as easily turned its shoulders toward the front or back of its body, giving it about a 50-50 chance of emerging in the easier, face-forward position. If the infant were born facing backward, the australopithecine mother--like modern human mothers--may well have benefited from some kind of assistance.

Growing Bigger Brains

IF BIPEDALISM ALONE did not introduce into the process of childbirth enough difficulty for mothers to benefit from assistance, then the expanding size of the hominid brain certainly did. The most significant expansion in adult and infant brain size evolved subsequent to the australopithecines, particularly in the genus Homo. Fossil remains of the pelvis of early Homo are quite rare, and the best-preserved specimen, the 1.6-million-year-old Nariokotome fossil from Kenya, is an adolescent often referred to as Turkana Boy. Researchers have estimated that the boy's adult relatives probably had brains about twice as large as those of australopithecines but still only two thirds the size of modern human brains.

By reconstructing the shape of the boy's pelvis from fragments, Christopher B. Ruff of Johns Hopkins University and Alan Walker of Pennsylvania State University have estimated what he would have looked like had he reached adulthood. Using predictable differences between male and female pelvises in more recent hominid species, they could also infer what a female of that species would have looked like and could estimate the shape of the birth canal. That shape turns out to be a flattened oval similar to that of the australopithecines. Based on these reconstructions, the researchers determined that Turkana Boy's kin probably had a birth mechanism like that seen in australopithecines.

In recent years, scientists have been testing an important hypothesis that follows from Ruff and Walker's assertion: the pelvic anatomy of early Homo may have limited the growth of the human brain until the evolutionary point at which the birth canal expanded enough to allow a larger infant head to pass. This assertion implies that bigger brains and roomier pelvises were linked from an evolutionary perspective. Individuals who displayed both characteristics were more successful at giving birth to offspring who survived to pass on the traits. These changes in pelvic anatomy, accompanied by assisted birth, may have allowed the dramatic increase in human brain size that took place from two million to 100,000 years ago.

Fossils that span the past 300,000 years of human evolution support the connection between the expansion of brain size and changes in pelvic anatomy. In the past 20 years, scientists have uncovered three pelvic fossils of archaic Homo sapiens: a male from Sima de los Huesos in Sierra Arapuerca, Spain (more than 200,000 years old); a female from Jinniushan, China (280,000 years old); and

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the male Kebara Neandertal--which is also an archaic H. sapiens--from Israel (about 60,000 years old). These specimens all have the twisted pelvic openings characteristic of modern humans, which suggests that their large-brained babies would most likely have had to rotate the head and shoulders within the birth canal and would thus have emerged facing away from the mother--a major challenge that human mothers face in delivering their babies safely.

The triple challenge of big-brained infants, a pelvis designed for walking upright, and a rotational delivery in which the baby emerges facing backward is not merely a contemporary circumstance. For this reason, we suggest that natural selection long ago favored the behavior of seeking assistance during birth because such help compensated for these difficulties. Mothers probably did not seek assistance solely because they predicted the risk that childbirth poses, however. Pain, fear and anxiety more likely drove their desire for companionship and security.

Psychiatrists have argued that natural selection might have favored such emotions--also common during illness and injury--because they led individuals who experienced them to seek the protection of companions, which would have given them a better chance of surviving [see "Evolution and the Origins of Disease," by Randolph M. Nesse and George C. Williams; SCIENTIFIC AMERICAN, November 1998]. The offspring of the survivors would then also have an enhanced tendency to experience such emotions during times of pain or disease. Taking into consideration the evolutionary advantage that fear and anxiety impart, it is no surprise that women commonly experience these emotions during labor and delivery.

Modern women giving birth have a dual evolutionary legacy: the need for physical as well as emotional support. When Sophia Pedro gave birth in a tree surrounded by raging floodwaters, she may have had both kinds of assistance. In an interview several months after her helicopter rescue, she told reporters that her mother-in-law, who was also in the tree, helped her during delivery. Desire for this kind of support, it appears, may well be as ancient as humanity itself.

MORE TO EXPLORE

Human Birth: An Evolutionary Perspective. Wenda R. Trevathan. Aldine de Gruyter, 1987.

Birth as an American Rite of Passage. Robbie Davis-Floyd. University of California Press, 1993.

Bipedalism and Human Birth: The Obstetrical Dilemma Revisited. Karen R. Rosenberg and Wenda R. Trevathan in Evolutionary Anthropology, Vol.4, No. 5, pages 161-168, 1996.

On Fertile Ground: A Natural History of Human Reproduction. Peter T. Ellison. Harvard University Press, 2001.

RELATED ARTICLE: Childbirth across Cultures

THE COMPLICATED CONFIGURATION of the human birth canal is such that laboring women and their babies benefit--by lower rates of mortality, injury and anxiety--from the assistance of others. This evolutionary reality helps to explain why attended birth is a near universal feature of human cultures. Individual women throughout history have given birth alone in certain circumstances, of course. But much more common is the attendance of familiar friends and relatives, most of whom are women. (Men may be variously forbidden, tolerated, welcomed or even required at birth.) In Western societies, where women usually give birth in the presence of strangers, recent research on birth practices has also shown that a doula--a person who provides social and emotional support to a woman in labor--reduces the rate of complications.

In many societies, a woman may not be recognized as an adult until she has had a baby. The preferred location of the delivery is often specified, as are the positions that the laboring women assume. The typical expectation in Western culture is that women should give birth lying flat on their backs on a bed, but in the rest of the world the most prevalent position for the delivery is upright--sitting, squatting or, in some cases, standing.--K.R.R. and W.R.T.

THE AUTHORS

KAREN R. ROSENBERG and WENDA R. TREVATHAN THAN bring different perspectives to the study of human birth. Rosenberg, a paleoanthropologist at the University of Delaware, specializes in pelvic morphology and has studied hominid fossils from Europe, Israel, China and South Africa. About 15 years ago she began studying the pelvis as a way to reconstruct the evolution of the birth process. That's when she met Trevathan, a biological anthropologist at New Mexico State University, whose particular interests include childbirth, maternal behavior, sexuality, menopause and evolutionary medicine. Both authors have experienced birth firsthand: Rosenberg has two daughters, and Trevathan is trained as a midwife.