The Birth of Childhood

Unlike other apes, humans depend on their parents for a long period after weaning. But when—and why—did our long childhood evolve?

Mel was just 3.5 years old when his mother died of pneumonia in 1987 in Tanzania. He had still been nursing and had no siblings, so his prospects were grim. He begged weakly for meat, and although adults gave him scraps, only a 12-year-old named Spindle shared his food regularly, protected him, and let him sleep with him at night. When Spindle took off for a month, another adolescent, Pax, came to Mel's rescue, giving him fruit and a place to sleep until Spindle returned. Mel survived to age 10.

Fortunately for Mel, he was an orphan chimpanzee living in the Gombe Stream National Park rather than a small child living in the slums of a big city. With only sporadic care from older children, a 3-year-old human orphan would not have survived.

Mel's story illustrates the uniqueness of one facet of human life: Unlike our close cousins the chimpanzees, we have a prolonged period of development after weaning, when children depend on their parents to feed them, until at least age 6 or 7. Street children from Kathmandu to Rio de Janeiro do not survive on their own unless they are at least 6. "There's no society where children can feed themselves after weaning," says anthropologist Kristen Hawkes of the University of Utah in Salt Lake City. By contrast, "chimpanzees don't have childhoods. They are independent soon after weaning," says anthropologist Barry Bogin of Loughborough University in Leicestershire, U.K.

Humans are also the only animals that stretch out the teenage years, having a final growth spurt and delaying reproduction until about 6 years after puberty. On average, women's first babies arrive at age 19, with a worldwide peak of first babies at age 22.5. This lengthy period of development—comprised of infancy, juvenile years, and adolescence—is a hallmark of the human condition; researchers have known since the 1930s that we take twice as long as chimpanzees to reach adulthood. Even though we are only a bit bigger than chimpanzees, we mature and reproduce a decade later and live 2 to 3 decades longer, says Bogin.

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Hear more about childhood's beginning in a podcast with author Ann Gibbons.

Given that we are unique among mammals, researchers have been probing how this pattern of growth evolved. They have long scrutinized the few, fragile skulls and skeletons of ancient children and have now developed an arsenal of tools to better gauge how childhood has changed over the past 3 million years. Researchers are scanning skulls and teeth of every known juvenile with electron microscopes, micro–computed tomography scans, or powerful synchrotron x-rays and applying state-of-the-art methods to create three-dimensional virtual reconstructions of the skulls of infants and the pelvises of mothers. They're analyzing life histories in traditional cultures to help understand the advantages of the human condition. In addition, some new fossils are appearing. On page 1089 of this issue, researchers report the first nearly complete pelvis of a female *Homo erectus*, which offers clues to the prenatal growth of this key human species.

All of this is creating some surprises. One direct human ancestor, whose skeleton looks much like our own, turns out to have grown up much faster than we do. The life histories of our closest evolutionary cousins, the Neandertals, remain controversial, but some researchers suspect that they may have had the longest childhoods of all. The new lines of evidence are helping researchers close in on the time when childhood began to lengthen. "Evidence suggests

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Changing face of childhood. Childhood has more than doubled in length in modern humans as compared to chimpanzees and the Dikika baby australopithecine (*reconstructed in lower left*). Delaying childbirth allows for bigger, stronger mothers who can give birth more frequently, as seen for example in traditional hunter-gatherer societies (*upper right*).

that much of what makes our life history unique took shape during the evolution of the genus *Homo* and not before,” says anthropologist Holly Smith of the University of Michigan, Ann Arbor.

Childhood Stages	Age at weaning (years)	Age at eruption of first molar (years)	Female age at first breeding (years) (estimated by 3rd molar eruption in fossils)	Average maximum life span (years)
Chimpanzees, *Pan troglodytes*	4.0	4.0	11.5	45
Lucy, *Australopithecus afarensis*	4.0?	4.0?	11.5	45
Homo erectus	?	4.5	14.5 (est.)	60? (est.)
Modern humans, *Homo sapiens*	2.5	6.0	19.3	70

Milestones. Key events show that modern humans live slower and die later than our ancestors did.

Live fast, die young

Back in 1925, Australian anatomist Raymond Dart announced the discovery of that rarest of rare specimens, the skull of an early hominin child. Dart estimated that the australopithecine he called the Taung baby had been about 6 years old when it died about 2 million years ago, because its first permanent molar had erupted. As modern parents know, the first of the baby teeth fall out and the first permanent molars appear at about age 6. Dart assumed that early hominins—the group made up of humans and our ancestors but not other apes—matured on much the same schedule as we do, an assumption held for 60 years. Growing up slowly was seen as a defining character of the human lineage.

Then in 1984, anatomists Christopher Dean and Timothy Bromage tested a new method to calculate the chronological ages of fossil children in a lab at University College London (UCL). Just as botanists add up tree rings to calculate the age of a tree, they counted microscopic lines on the surface of teeth that are laid down weekly as humans grow. The pair counted the lines on teeth of australopithecine children about as mature as the Taung child and were confounded: These hominin children were only about 3.5 years old rather than 6. They seemed to be closer to the chimpanzee pattern, in which the first permanent molar erupts at about age 3.5. “We concluded that [the australopithecines] were more like living great apes in their pace of development than modern humans,” says Dean.

Their report in *Nature* in 1985 shook the field and focused researchers on the key questions of when and why our ancestors adopted the risky strategy of delaying reproduction. Many other slow-growing, large-bodied animals, such as rhinos, elephants, and chimpanzees, are now threatened with extinction, in part because they delay reproduction so long that their offspring risk dying before they replace themselves. Humans are the latest to begin reproducing, yet we seem immune from those risks, given that there are 6.6 billion of us on the planet. “When did we escape those constraints? When did we extend our childhood?” asks biological anthropologist Steven Leigh of the University of Illinois, Urbana-Champaign.

The Taung baby and the other australopithecine children, including the relatively recent discovery of a stunning fossil of a 3-year-old *Australopithecus afarensis* girl from Dikika, Ethiopia, show that it happened after the australopithecines. So researchers have zeroed in on early *Homo*, which appeared in Africa about 2 million years ago.

Unfortunately, there are only a few jaw bits of early *Homo* infants and young children to nail down their ages. Most of what we know comes from a single skeleton, a *H. erectus* boy who died about 1.6 million years ago near Lake Turkana, Kenya. *H. erectus* was among the first human ancestors to share many key elements of the modern human body plan, with a brain considerably larger than that of earlier hominins. And unlike the petite australopithecines, this Turkana youth was big: He weighed 50 kilograms, stood 163 centimeters tall, and looked like he was 13 years old, based on modern human standards. Yet two independent tooth studies suggested ages from 8 or 9 to 10.5 years old.

Big for his age. The 8-year-old Turkana Boy, reconstructed here, grew up faster than modern humans do.

Now a fresh look at the skeleton concludes that, despite the boy’s size, he was closer to 8 years old when he died. Dean and Smith make this case in a paper in press in an edited volume, *The First Humans: Origin of the Genus* Homo. The skeleton and tooth microstructure of the boy and new data on other members of his species suggest that he attained more of his adult height and mass earlier than modern human children do. Today, “you won’t find an 8-year-old boy with body weight, height, and skeletal age that are so much older,” says Dean.

He and Smith concluded that the boy did not experience a “long, slow period of growth” after he was weaned but grew up earlier, more like a chimpanzee. They estimate the species’ age at first reproduction at about 14.5, based on the eruption of its third molar, which in both humans and chimpanzees erupts at about the age they first reproduce. This 8-year-old Turkana Boy was probably more independent than a 13-year-old modern human, the researchers say, suggesting that *H. erectus* families were quite different from ours and did not stay together as long.

The new, remarkably complete female pelvis described in this issue, however, suggests that life history changes had begun in *H. erectus*. Researchers led by Sileshi Semaw of the Stone Age Institute at Indiana University, Bloomington, found the pelvis in the badlands of Gona, Ethiopia. They present a chain of inference that leads from pelvis, to brain size, to life history strategy.

They assume that the nearly complete

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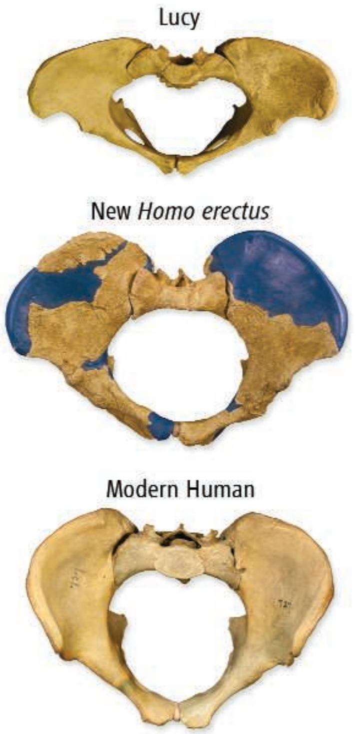
pelvis belongs to *H. erectus*, because other *H. erectus* fossils were found nearby and because it resembles fragmentary pelvises for the species. Lead author Scott Simpson of Case Western Reserve University in Cleveland, Ohio, paints a vivid picture of a short female with wide hips and an "obstetrically capacious" pelvic opening that could have birthed babies with brain sizes of up to 315 milliliters. That's 30% to 50% of the adult brain size for this species and larger than previously predicted based on a reconstruction of the Turkana Boy's incomplete pelvis. However, the new estimate does match with newborn brain size predicted by the size of adult brains in *H. erectus*, says Jeremy DeSilva of Worcester State College in Massachusetts, who made such calculations online in September in the *Journal of Human Evolution*.

The wide pelvis suggests *H. erectus* got a head start on its brain development, putting on extra gray matter in utero rather than later in childhood. That's similar to living people, whose brains grow rapidly before birth, says Simpson. But if *H. erectus*'s fetal growth approached that of modern humans, it built proportionately more of its brain before birth, because its brain never became as massive as our own.

Thus, *H. erectus* grew its brain before birth like a modern human, while during childhood it grew up faster like an ape. With a brain developing early, *H. erectus* toddlers may have spent less time as helpless children than modern humans do, says paleoanthropologist Alan Walker of Pennsylvania State University in State College. This suggests *H. erectus* children were neither chimplike nor humanlike but perhaps somewhere in between: "Early *H. erectus* possessed a life history unlike any species living today," write Dean and Smith. "If you look at its morphology, it fits in our genus, *Homo*," says Smith. "But in terms of life history, they fit with australopithecines."

Live slow, die old?

If *H. erectus* was just beginning to slow down its life history, when did humans take the last steps, to our current late-maturing life plan? Three juvenile fossil members of *H. antecessor*, who died 800,000 years ago in Atapuerca, Spain, offer tantalizing clues. An initial study in 1999, based on rough estimates of tooth eruption, found that this species matured like a modern human, says José María Bermúdez de Castro of the Museo Nacional de Ciencias Naturales in Madrid. Detailed studies of tooth microstructure are eagerly awaited to confirm this.



Ancient hipsters. A fossil female pelvis from *Homo erectus* (*middle*) shows that the species could birth babies with bigger heads than Lucy's species (*top*) but smaller than a modern human's.

In the meantime, another recent study has shown that childhood was fully extended by the time the first members of our species, *H. sapiens*, appeared in northern Africa about 200,000 years ago. In 2007, researchers examined the daily, internal tooth lines of a *H. sapiens* child who lived 160,000 years ago in Jebel Irhoud, Morocco. They used x-rays from a powerful particle accelerator in Grenoble, France (*Science*, 7 December 2007, p. 1546), to study the teeth without destroying them and found that the 8-year-old Jebel Irhoud child had grown as slowly as a modern 8-year-old, according to Harvard University paleoanthropologist Tanya Smith, who co-led the study.

That analysis narrowed the window of time when humans evolved the last extension of our childhood to between 800,000 years ago and 200,000 years ago. To constrain it still further, Tanya Smith and her colleagues recently trained their x-ray vision on our closest relatives: the extinct Neandertals, who shared their last ancestor with us about 500,000 years ago. First, the researchers sliced a molar of a Belgian Neandertal that was at the same stage of dental development as the 8-year-old Jebel Irhoud child and counted its internal growth lines. They found that it had reached the same dental milestones more rapidly and proposed that Neandertals grew up faster than we do. That suggests that a fully extended childhood evolved only in our species, in the past 200,000 years.

But Tanya Smith's results conflict with earlier studies by Dean and colleagues who also sliced Neandertal teeth and found that they had formed slowly, like those of modern humans. The case is not closed: Smith and paleontologist Paul Tafforeau of the European Synchrotron Radiation Facility in Grenoble, France, spent weeks last year imaging juvenile Neandertals and early members of *H. sapiens*, and they expect to publish within a year.

Meanwhile, new data with implications for Neandertal growth rates are coming in from other sources. The brain sizes of a Neandertal newborn and two infants show that they were at the upper end of the size range for modern humans, suggesting that their brains grew faster than ours after birth, according to virtual reconstructions by Christoph Zollikofer and anthropologist Marcia Ponce de León of the University of Zurich (*Science*, 12 September, p. 1429).

Those rapidly growing brains don't necessarily imply a rapid life history, warn

More siblings? Hutterite families often had nine children each.

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Zollikofer and Ponce de León. They argue that because Neandertals' brains were more massive, they did not complete brain growth earlier than modern humans even though they grew at a faster rate. "They have to get those bigger brains somehow," says Holly Smith. For now, Neandertals' life history remains controversial.

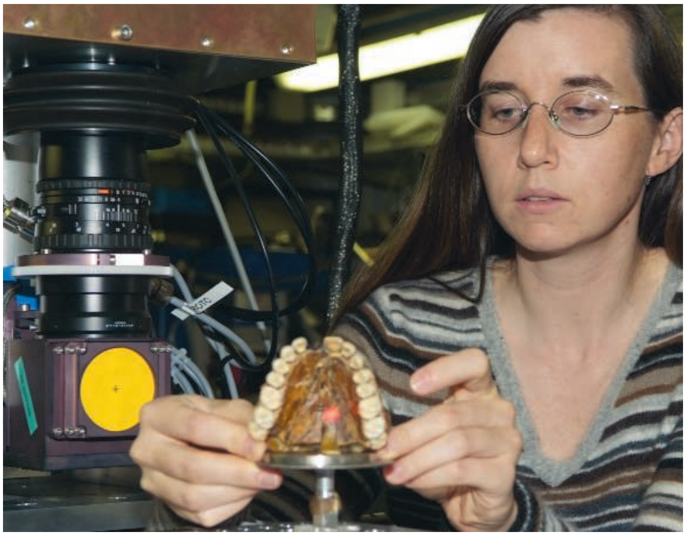
Why wait?

If childhood began to change in *H. erectus* and continued to get longer in our own species and possibly Neandertals, then the next question is why. What advantage did our ancestors gain from delaying reproduction so long? Many researchers agree that childhood allows us to learn from others, in order to improve our survival skills and prepare us to be better parents. Historically, researchers have also argued that humans need a long childhood to allow enough time for our larger brain to mature.

But in fact, a big brain doesn't directly cause the extension of childhood, because the brain is built relatively early. "Everyone speaks about slow human development, but the human brain develops very fast," says Zollikofer. It doubles in size in the first year of life and achieves 95% of its adult size by the age of 5 (although white matter grows at least to age 18). "We get our brains done; then, we sit around for much longer than other species before we reproduce," says Leigh. "It's almost like humans are building the outside, getting the scaffolding of the house up early, and then filling in after that."

However, there's a less direct connection between brains and life history: Big brains are so metabolically expensive that primates must postpone the age of reproduction in order to build them, according to a paper last year in the *Journal of Human Evolution* (*Science*, 15 June 2007, p. 1560). "The high metabolic costs of rapid brain growth require delayed maturation so that mothers can bear the metabolic burdens associated with high brain growth," says Leigh. "Fast brain growth tells us that maturation is late."

That's why Ponce de León and Zollikofer think that the Neandertals' rapid brain growth implies late, rather than early, maturation: Neandertal mothers must have been large and strong—and by implication, relatively old—to support infants with such big, fast-growing brains. Indeed, say the Zurich pair, Neandertals may have had even longer childhoods than we do now. Childhood, like brain size, may have reached its zenith in Neandertals and early *H. sapiens*. As our brains got smaller over the past 50,000 years, we might have begun reproducing slightly earlier than Neandertals.



Tooth time. Tanya Smith uses a synchrotron accelerator to x-ray fossil teeth (*above*); molar eruption helps age other specimens such as Turkana Boy (*left*).

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To explore such questions, recent interdisciplinary studies are teasing out the reproductive advantages of waiting to become parents. Many analyses cite an influential life history model by evolutionary biologist Eric Charnov of the University of New Mexico, Albuquerque. The model shows that it pays to have babies early if parents face a high risk of death. Conversely, mammals that face a lower risk of dying benefit if they wait to reproduce, because older mothers can grow bigger, stronger bodies that grow bigger babies, who are more likely to survive. "The driving force of a prolonged life history schedule is almost certainly a reduction in mortality rates that allows growth and life span to extend and allows for reproduction to extend further into adulthood in a more spread-out manner," says Dean.

Researchers such as Loughborough's Bogin have applied Charnov's model to modern humans, proposing that delaying reproduction creates higher quality human mothers. Indeed, humans start having babies 8 years later than chimpanzees, and both species stop by about age 45 to 50. But once human mothers begin, they more than make up for their delayed start, pushing out babies on average 3.4 years apart in traditional forager societies without birth control, compared with 5.9 years for wild chimpanzees, says Bogin. This rapid-fire reproduction produces more babies for human hunter-gatherers, who have peak fertility rates of 0.31 babies per given year compared with 0.22 for chimpanzees. And human mothers who start even later than age 19 have more surviving babies. For example, in the 1950s, the Anabaptist Hutterites of North America, who eschewed birth control, had their first babies on average at age 22 and then bore children every 2 years. They produced an amazing nine children per mother, says Bogin, who has studied the group.

Such fecundity, however, requires a village or at least an extended family with fathers and grandmothers around to help provision and care for the young. That's something that other primates cannot provide consistently, if at all, says Hawkes (*Science*, 25 April 1997, p. 535). She proposed that grandmothers' provisioning allows mothers to wean early and have babies more closely together, a vivid example of the way humans use social connections to overcome biological constraints—and allow mothers to have more babies than they could raise on their own. "Late maturation works well for humans because culture lets us escape the constraints other primates have," says Leigh.

The key is to find out when our ancestors were weaned, says Holly Smith. Younger weaning implies that mothers had enough social support to feed weaned children and space babies more closely. "Weaning tells us when *Homo* species start stacking their young," says Smith. Indeed, Dean and Louise Humphrey of the Natural History Museum in London are testing a method that detects the chemical signature of weaning in human teeth. Humans may be slow starters, but our social safety net has allowed us to stack our babies closely together—and so win the reproductive sweepstakes, leaving chimpanzees, and the extinct Neandertals, far behind.

–ANN GIBBONS