The Search for Adam and Eve

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Scientists are calling her Eve, but reluctantly. The name evokes too many wrong images -- the weak-willed figure in Genesis, the milk-skinned beauty in Renaissance art, the voluptuary gardener in "Paradise Lost" who was all "softness" and "meek surrender" and waist-length "gold tresses." The scientists' Eve -- subject of one of the most provocative anthropological theories in a decade -- was more likely a dark-haired, black-skinned woman, roaming a hot savanna in search of food. She was as muscular as Martina Navratilova, maybe stronger; she might have torn animals apart with her hands, although she probably preferred to use stone tools. She was not the only woman on earth, nor necessarily the most attractive or maternal. She was simply the most fruitful, if that is measured by success in propagating a certain set of genes. Hers seem to be in all humans living today: 5 billion blood relatives. She was, by one rough estimate, your 10,000th-great-grandmother.

When scientists announced their "discovery" of Eve last year, they rekindled perhaps the oldest human debate: where did we come from? They also, in some sense, confirmed a belief that existed long before the Bible. Versions of the Adam-and-Eve story date back at least 5,000 years and have been told in cultures from the Mediterranean to the South Pacific to the Americas. The mythmakers spun their tales on the same basic assumption as the scientists: that at some point we all share an ancestor. The scientists don't claim to have found the first woman, merely a common ancestor -- possibly one from the time when modern humans arose. What's startling about this Eve is that she lived 200,000 years ago. This date not only upsets fundamentalists (the Bible's Eve was calculated to have lived 5,992 years ago), it challenges many evolutionists' conviction that the human family tree began much earlier.

Sturdy and fruitful, Eve probably lived in a small group that scoured the plains for food. But where? 'We can't decide whether it was Asia or Africa.'

Douglas Wallace

Eve has provoked a scientific controversy bitter even by the standards of anthropologists, who have few rivals at scholarly sniping. Their feuds normally begin when someone's grand theory of our lineage is contradicted by the unearthing of a few stones or bones. This time, however, the argument involves a new breed of anthropologists who work in air-conditioned American laboratories instead of dessicated African rift valleys. Trained in molecular biology, they looked at an international assortment of genes and picked up a trail of DNA that led them to a single woman from whom we are all descended. Most evidence so far indicates that Eve lived in sub-Saharan Africa, although a few researchers think her home might have been southern China. Meanwhile, other geneticists are trying to trace our genes back to a scientifically derived Adam, a putative "great father" of us all. As is often the case, paternity is proving harder to establish: the molecular trail to Adam involves a different, more elusive sort of DNA.

The most controversial implication of the geneticists' work is that modern humans didn't slowly and inexorably evolve in different parts of the world, as many anthropologists believed. The evolution from archaic to modern Homo sapiens seems to have occurred in only one place, Eve's family. Then, sometime between 90,000 and 180,000 years ago, a group of her progeny left their homeland endowed apparently with some special advantage over every tribe of early humans they encountered. As they fanned out, Eve's descendants replaced the locals, eventually settling the entire world. Some "stones-and-bones" anthropologists accept this view of evolution, but others refuse to accept this interpretation of the genetic evidence. They think our common ancestor must have lived much farther in the past, at least a million years ago, because that was when humans first left Africa and began spreading out over the world, presumably evolving separately into the modern races. As the veteran excavator Richard Leakey declared in 1977: "There is no single center where modern man was born."

To find Eve, she first had to persuade 147 pregnant women to donate their babies' placentas to science.

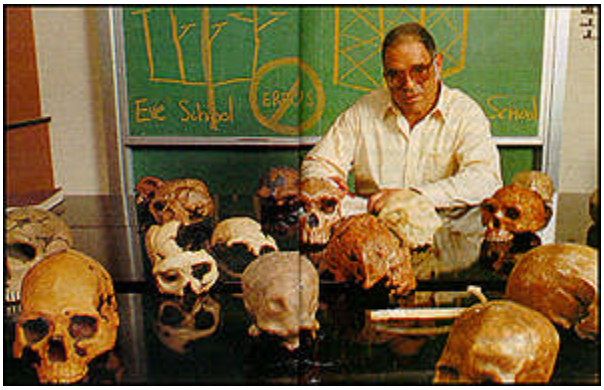
Rebecca Cann

But now geneticists are inclined to believe otherwise, even if they can't agree where the center was. "If it's correct, and I'd put money on it, this idea is tremendously important," says Stephen Jay Gould, the Harvard paleontologist and essayist. "It makes us realize that all human beings, despite

differences in external appearance, are really members of a single entity that's had a very recent origin in one place. There is a kind of biological brotherhood that's much more profound than we ever realized."

This brotherhood was not always obvious in Chicago two months ago, when the Eve hypothesis was debated by the American Anthropological Association. Geneticists flashed diagrams of DNA, paleoanthropologists showed slides of skulls and everyone argued with everyone else. "What bothers many of us paleontologists," said Fred Smith of the University of Tennessee, "is the perception that this new data from DNA is so precise and scientific and that we paleontologists are just a bunch of bumbling old fools. But if you listen to the geneticists, you realize they're as divided about their genetic data as we are about the bones. We may be bumbling fools, but we're not any more bumbling than they are." For all their quarrels, though, the two groups left Chicago convinced they're closer than ever to establishing the origin of modern humanity. To make sense of their bumbling toward Eden, it may be best to go back to one ancient relative accepted by all scientists. That would be the chimpanzee.

Until the molecular biologists came along, the role of the chimpanzee in evolution rested on the usual evidence: skeletons. Scientists have relied on bones ever since the 1850s, when Darwin published his theory of evolution and some quarriers unearthed a strange skeleton in Germany's Neander Valley. Was the stooped apelike figure a remnant of an ancient race? Leading scientists thought not. One declared it a Mongolian soldier from the Napoleonic Wars. A prominent anatomist concluded it was a recent "pathological idiot."



' I believe we have a long history of people constantly mixing with one another and cooperating with one another and evolving into one great family.'

Milford Wolpoff

But more skeletons kept turning up across Europe and Asia. Anthropologists realized that Neanderthal man was one of many brawny, beetle-browed humans who mysteriously disappeared about 34,000 years ago. These early Homo sapiens, incidentally, were not stooped (that first skeleton was hunched with arthritis). Nor did they fit the stereotype of the savage cave man. Their skulls were thicker than ours, but their brains were as large. Their fossils show that they cared for the infirm elderly and buried the dead. It seemed they might be our ancestors after all.

Meanwhile, fossil hunters in Asia more than a half century ago found the still older bones of Java man and Peking man, who had smaller brains and even more muscular bodies. These skeletons dated back as far as 800,000 years. Perhaps they represented evolutionary dead ends. Or perhaps they, too, were human ancestors, with their descendants evolving into modern Asians while the Neanderthals were becoming modern Europeans -- a process of racial differentiation that lasted a million years. Either way, it appeared that all these ancient humans traced their lineage back to Africa, because that was the only place with evidence of humans living more than a million years ago. Stone tools were invented there about 2 million years ago by an ancestor named Homo habilis ("Handy Man"). Before him was Lucy, whose 3 million-year-old skeleton was unearthed in the Ethiopian desert in 1974.

(Her discoverers celebrated by staying up all night drinking beer, and they named her after the Beatles' song that kept blaring on the camp's tape player, "Lucy in the Sky with Diamonds.") Lucy was three and a half feet tall and walked erect -- not ape, not quite human. At some point her hominid ancestors had begun evolving away from the forebears of our closest relative, the chimpanzee.

But when? Most anthropologists thought it was at least 15 million years ago, because they had found bones from that era of an apelike creature who seemed to be ancestral to humans but not apes. Then, for the first time, geneticists intruded with contradictory evidence, led in 1967 by Vincent Sarich and Allan Wilson of the University of California, Berkeley. They drew blood from baboons, chimps and humans, then looked at the molecular structure of a blood protein that was thought to change at a slow, steady rate as a species evolved. There were major differences between the molecules of chimps and baboons, as expected, since the two species have been evolving separately for 30 million years. But the difference between humans and chimps was surprisingly small -- so small, the geneticists concluded, that they must have parted company just 5 million years ago. Other geneticists used different techniques and came up with a figure of 7 million years.

Genes, like family names, die out. 'It's an inevitable consequence of reproduction. Lineages will be going extinct all the time.'

John Avise

Traditional anthropologists did not appreciate being told their estimates were off by 8 million or 10 million years. The geneticists' calculation was dismissed and ignored for more than a decade, much to Wilson's displeasure. "He was called a lunatic for 10 years. He's still sensitive," recalls Rebecca Cann, a former colleague at Berkeley who is now at the University of Hawaii. But eventually the geneticists were vindicated by the bones themselves. As more fossils turned up, anthropologists realized that the 15 million-year-old bones didn't belong to a human ancestor and that chimps and humans did indeed diverge much more recently.

Now Wilson, who won a MacArthur "genius grant" in 1986, is once again trying to speed up evolution. The Eve hypothesis, being advanced both by his laboratory and by a group at Emory University, is moving up the date when the races of humanity diverged -- and once again Wilson faces resistance. Some anthropologists aren't happy to see Neanderthal and Peking man removed from our lineage, consigned to dead branches of the family tree. Wilson likes to remind the critics of

the last fight. "They're being dragged slowly along," he says. "They'll eventually come around."

To find Eve, Cann first had to persuade 147 pregnant women to donate their babies' placentas to science. The placentas were the easiest way to get large samples of body tissue. Working with Wilson and a Berkeley biologist, Mark Stoneking, Cann selected women in America with ancestors from Africa, Europe, the Middle East and Asia. Her collaborators in New Guinea and Australia found Aboriginal women there. The babies were born, the placentas were gathered and frozen, and the tissue analysis began at Wilson's lab in Berkeley. The tissues were ground in a souped-up Waring blender, spun in a centrifuge, mixed with a cell-breaking detergent, dyed flourescent and spun in a centrifuge again. The result was a clear liquid containing pure DNA.

This was not the DNA in the nucleus of the babies' cells -- the genes that determine most physical traits. This DNA came from outside the nucleus, in a compartment of the cell called the mitochondrion, which produces nearly all the energy to keep the cell alive. Scientists didn't learn that the mitochondrion contained any genes until the 1960s. Then in the late 1970s they discovered that mitochondrial DNA was useful for tracing family trees because it's inherited only from the mother. It's not a mixture of both parents' genes, like nuclear DNA, so it preserves a family record that isn't scrambled every generation. It's altered only by mutations -- random, isolated mistakes in copying the genetic code, which are then passed on to the next generation. Each random mutation produces a new type of DNA as distinctive as a fingerprint. (The odds against two identical mitochondrial DNA's appearing by chance are astronomical because there are so many ways to rearrange the units of the genetic code.)

To study these mutations, the Berkeley researchers cut each sample of DNA into segments that could be compared with the DNA of other babies. The differences were clear but surprisingly small. There weren't even telltale distinctions between races. "We're a young species, and there are really very few genetic differences among cultures," Stoneking says. "In terms of our mitochondrial DNA, we're much more closely related than almost any other vertebrate or mammalian species. You find New Guineans whose DNA is closer to other Asians' than to other New Guineans'." This may seem odd, given obvious racial differences. In fact, though, many differences represent trivial changes. Skin color, for instance, is a minor adaptation to climate -- black in Africa for protection from the sun, white in Europe to absorb ultraviolet radiation that helps produce vitamin D. It takes only a few thousand years of evolution for skin color to change. The important changes -- in brain size, for instance -- can take hundreds of thousands of years.

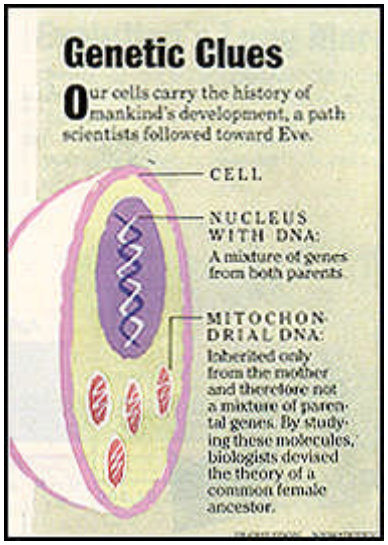
The babies' DNA seemed to form a family tree rooted in Africa. The DNA fell into two general categories, one found only in some babies of recent African descent, and a second found in everyone else and the other Africans. There was more diversity among the exclusively African group's DNA, suggesting that it had accumulated more mutations because it had been around longer -- and thus was the longest branch of the family tree. Apparently the DNA tree began in Africa, and then at some point a group of Africans emigrated, splitting off to form a second branch of DNA and carrying it to the rest of the world.

All the babies' DNA could be traced back, ultimately, to one woman. In itself that wasn't surprising, at least not to statisticians familiar with the quirks of genetic inheritance. "There must be one lucky mother," Wilson says. "I worry about the term 'Eve' a little bit because of the implication that in her generation there were only two people. We are not saying that. We're saying that in her generation there was some unknown number of men and women, probably a fairly large number, maybe a few thousand." Many of these other women presumably are also our ancestors, because their nuclear genes would have been passed along to sons and daughters and eventually would have reached us. But at some point these other women's mitochondrial genes disappeared because their descendants failed to have daughters, and so the mitochondrial DNA wasn't passed along. At first glance it may

seem inconceivable that the source of all mitochondrial DNA was a single woman, but it's a well-established outcome of the laws of probability.

You can get a feel for the mathematics by considering a similar phenomenon: the disappearance of family names. Like mitochondrial DNA, these are generally passed along by only one sex -- in this case, male. If a son marries and has two children, there's a one-in-four chance that he'll have two daughters. There's also a chance that he won't have any children. Eventually the odds catch up and a generation passes without a male heir, and the name disappears. "It's an inevitable consequence of reproduction," says John Avise, a geneticist at the University of Georgia. "Lineages will be going extinct all the time." After 20 generations, for instance, it's statistically likely that only 90 out of 100 original surnames will disappear. Avise cites the history of Pitcairn Island in the Pacific, which was settled in 1790 by 13 Tahitian women and six British sailors who had mutinied on the Bounty. After just seven generations, half of the original names have disappeared. If the island remained isolated, eventually everyone would have the same last name. At that point a visitor could conclude that every inhabitant descended from one man -- call him the Pitcairn Adam.

So thus there must be a mitochondrial Eve, and even traditional anthopologists can't really argue against her existence. What shocked them about Mitochondrial Mom was her birthday, which the Berkeley researchers calculated by counting the mutations that have occurred to her DNA. They looked at the most distant branches of the family tree -- the DNA types most different from one another -- and worked backward to figure out how many steps it would have taken for Eve's original DNA to mutate into these different types. They assumed that these mutations occurred at a regular rate -- a controversial assumption that might be wrong, but which has been supported by some studies of humans and animals. Over the course of a million years, it appears that 2 to 4 percent of the mitochondrial DNA components will mutate. By this molecular calculus, Eve must have lived about 200,000 years ago (the range is between 140,000 and 290,000 years). This date, published this past January by the Berkeley group, agrees with the estimate of a team of geneticists led by Douglas Wallace of Emory University.



But the Emory researchers think Eve might have lived in Asia. They base their conclusion also on mitochondrial DNA, which they gathered from the blood of about 700 people on four continents. They used different methods in chopping up the DNA and arranging the types in a family tree. Their tree also goes back to one woman, who lived 150,000 to 200,000 years ago, they estimate. Unlike the Berkeley researchers, however, they found that the races have distinctive types of DNA. They also found that the human DNA type most similar to that of apes occurred at the highest frequency in

Asia, making that the likely root of the family tree. Wallace's data suggests that Eve can be traced to southeast China, but he cautions that this is only one possible interpretation of the data. "If we make other assumptions, we can run our data through a computer and come up with a family tree starting in Africa," he says. "So I'm not ruling out Africa. I'm just saying that we can't yet decide whether it's Asia or Africa."

The rival geneticists are quick to criticize one another. Wallace faults the Berkeley researchers for getting most of their African DNA samples from American blacks, whose ancestors could have mixed with Europeans and American Indians. The Berkeley researchers insist that their study is better because they chopped the DNA into smaller pieces, enabling them to analyze differences more carefully. Both groups acknowledge that there's room for improvement, and they're planning to gather more samples and look more closely at the DNA's structure.

At the moment, the evidence seems to favor an African Eve, because other genetic studies (of nuclear DNA) also point to an origin there and because that's where the earliest fossils of modern humans have been found. But wherever Eve's home was, the rival geneticists agree that she lived relatively recently, and this is what provokes anthropologists to start arguing -- often with Biblical metaphors of their own.

If Eve lived within the past 200,000 years, she may have been a modern human, perhaps one of the first to appear. In that case she might have looked like a more muscular version of today's Africans. Or maybe it was her descendants who evolved into modern humans. Eve herself might have been our immediate ancestor, an archaic Homo sapiens, and therefore brawnier, with a large, protruding face and a forehead receding behind prominent brow ridges. She was certainly a hunter-gatherer, probably much like today's Bushmen in southern Africa, living in a group of maybe 25, carrying a nursing child across the plains in search of food. Humans around the world -- Java man, Peking man -- were living like this for hundreds of thousands of years before our mitochondrial Eve.

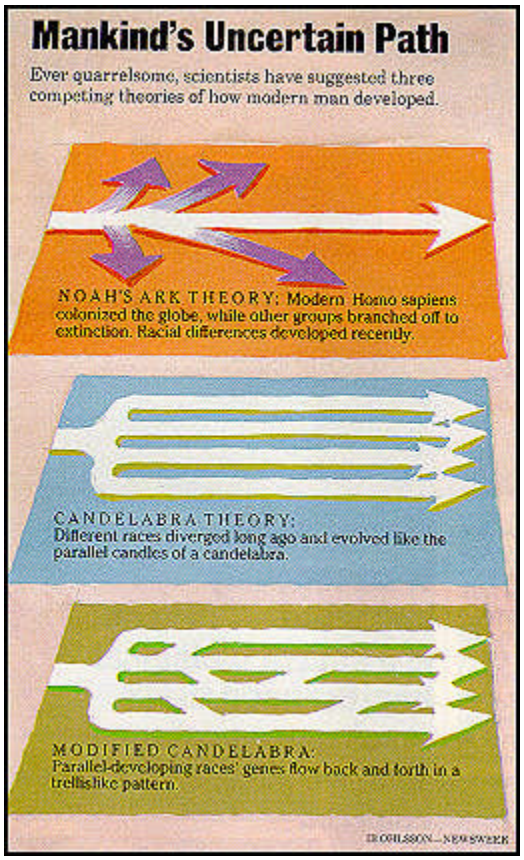
The question is: what happened to all the other populations around the world? For their women's mitochondrial genes apparently all vanished. The Berkeley biologists conclude that everyone outside Africa stems from a group of Eve's descendants who left their homeland between 90,000 and 180,000 years ago. As they moved across Asia and Europe, they would have encountered Neanderthals and populations of archaic Homo sapiens. They were probably outnumbered in many places. But wherever the daughters of Eve went, only their mitochondrial DNA survived.

Did the immigrants kill the natives? Possibly, but the conquests may have been peaceful. Because they were modern humans, Eve's descendants were less muscular than the archaic natives, but they were more organized, more able to plan ahead. They could make better stone tools. As they prospered and multiplied, consuming more of the local fruit and game, the natives would have suffered; a slight increase in their mortality rate could have led to their extinction in just a thousand years.

The immigrants may have been able to interbreed with the locals. Some anthropologists see physical vestiges of the Neanderthals in modern Europeans, and the Eve hypothesis doesn't rule out the possibility that the Neanderthals' nuclear genes were passed along to us. But the fact remains that the Neanderthals' mitochondrial genes all disappeared after Eve's descendants arrived, so both the Berkeley and Emory biologists suspect there was little or no mixing. Maybe the immigrants were so different that they couldn't interbreed. Or maybe they simply shunned the natives as being too "primitive." The Neanderthals' attempts at courtship presumably suffered if, as some scientists speculate, they lacked modern humans' power of speech.

This question of interbreeding is the crux of the bones-molecules debate. The geneticists' most vehement critic is Milford Wolpoff, a University of Michigan paleoanthropologist who believes our common ancestor lived closer to a million years ago. "The most obvious conclusion from the genetic evidence," he says, "is that Eve's descendants spread out of Africa and weren't incorporated at all into the local populations. I find that incredible. In recorded history, there always has been intermixing as populations moved or villages exchanged wives. I believe we have a long history of people constantly mixing with one another and cooperating with one another and evolving into one great family." Wolpoff finds his version of evolution more satisfying than "this business about Eve showing the common nature of everything." If Eve's descendants wiped out all rivals, Wolpoff suggests, maybe the theory should be named after her murderous son, Cain.

Actually, the more common term for this idea is Noah's Ark, coined by Harvard's W. W. Howells in describing the two classic schools of anthropological thought on the origin of modern humans. One school believes that a small group of modern humans appeared in one place recently -- perhaps 100,000 to 200,000 years ago -- and colonized the entire world, like the survivors of Noah's ark. The other populations were not inexorably climbing the ladder or the tree of evolution -- they were more like twigs on a bush or the arms of a hatrack, branching off to an inglorious end. The idea of a recent common origin for humanity was held by many anthropologists long before DNA provided supporting evidence.



The opposing school believes in what Howells called the "candelabra hypothesis": the different races diverged long ago and evolved independently into modern humans, progressing like the parallel candles of candelabra. This view became prominent in 1962 with Carleton Coon's book "The Origin of Races." He insisted that modern humans did not suddenly appear, "fully formed as from the brow of Zeus," in one place. "I could see that the visible and invisible differences between living races could be explained only in terms of history," wrote Coon, a University of Pennsylvania anthropologist. "Each major race had followed a pathway of its own through the labyrinth of time."

Unfortunately, Coon published his theory along with a speculation that was denounced as racist. He suggested that African civilization was less advanced because black people were the last to evolve into modern humans. Although the first hominids may have arisen in Africa, Coon said, the evolution of modern humans seemed to occur first in Europe and Asia. "If Africa was the cradle of mankind, it was only an indifferent kindergarten." He couldn't have been more wrong. Bones subsequently discovered in Africa are believed to be from modern humans living there about 100,000 years ago. These bones (as well as some from Israel that might be as old) represent the earliest known modern humans. Before their discovery it was assumed that modern humans didn't

evolve until 35,000 years ago, which is when they first appear in the European fossil records. So blacks were hardly the last to reach modernity.

Coon's mistake didn't invalidate the basic candelabra hypothesis, which is still popular in a modified version. Wolpoff prefers to think of a trellis: the separate races gradually evolving along parallel lines but connected by a network of genes flowing back and forth. The Neanderthals turned into modern Europeans while Peking man's descendants were becoming modern Chinese. Immigrants brought in new genes, but the natives' basic traits survived. This would explain why both the Neanderthals and the modern Europeans have big noses, why Peking man and current residents of Beijing have flat faces, why today's Aboriginal Australians have flat foreheads like Java man. These similarities presumably wouldn't persist if the ancient natives had disappeared when Eve's descendants arrived.

Other anthropologists, however, find these similarities unconvincing. It might just be a coincidence that modern Europeans have big noses like the Neanderthals. To the Noah's-ark school, what's striking are the differences between ancients and moderns. Modern Europeans, for instance, are much less stocky than Neanderthals -- their arms and legs are proportioned more like those of humans from the tropics, as Eve's presumably were. And there's no clear sign in the fossil records of a transition from Neanderthal to modern. Some anthropologists cite bones that might belong to hybrids of immigrants and natives, but these interpretations are disputed.

"I don't rule out the possibility that there was interbreeding, but I don't see it in the fossils," says The British Museum's Christopher Stringer. "In the two areas [where] we have the best fossil evidence, Europe and Southwest Asia, the gap between archaic and modern people is very large. The entire skeleton and brain case changed. I think the fossil evidence is clearly signaling replacement of the archaic population. I was delighted to see the DNA results support this view."

Most anthropologists, though, are still skeptical. They don't reject outright the genetic evidence, but they don't accept it flatly, either. After the mistakes of the past, they're leery of any grand new theory about human evolution. They rightly point out that the geneticists' molecular clock could be way off -- change a few assumptions and Eve's birthday could move back hundreds of thousands of years, bringing ancients like Peking man back into our lineage. Above all, anthropologists would like to see the corroborating bones.

"We don't know what's going on here," says the University of Pennsylvania's Alan Mann. "Maybe we are dealing with a dramatic jump. Maybe the origin of creatures like us occurred very recently. Certainly the mitochondrial data is a significant advance. But there really isn't any good fossil evidence from that period to back it up. If you look at the fossils, the good evidence on Africa can be placed on the palm of your hand. In this field, a person kicks over a stone in Africa, and we have to rewrite the textbooks."

'This idea is tremendously important . . . There is a kind of biological brotherhood that's much more profound than we ever realized.'

--Stephen Jay Gould

So the fossil hunters will keep digging -- now they have something specific to look for in the sediments of 200,000 years ago. Maybe they'll vindicate the geneticists once again, but the geneticists aren't waiting to find out. They're already trying to expand the Eve theory by finding Adam. Researchers in England, France and the United States have begun looking at the Y chromosome, which is passed along only on the male side. Tracing it is difficult because it's part of the DNA in the cell's nucleus, where there are many more genes than in the mitochondrion. This Adam will be the one lucky father whose descendants always had at least one son every generation. He may have been hunting and gathering while Eve was, or he may have lived at another time (though it would cast doubt on the Eve hypothesis if the time and place of his birth were too distant). The researchers hope to get an answer within several years.

In the meantime, there is one temporary candidate for an Adam -- not the one scientists are looking for but one defined simply as a man from whom we are all descended. Since we are all descended from Eve's daughters, any common ancestor of theirs would be a common ancestor to everyone today. This wouldn't necessarily be Eve's husband. For all we know, she may have had more than one. But her daughters all certainly had the same maternal grandfather. So, at least for now, the only safe conclusion is that Adam was Eve's father.

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