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They Don't Make Homo Sapiens Like They Used To

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For decades the consensus view—among the public as well as the world's preeminent biologists—has been that human evolution is over. Since modern Homo sapiensemerged 50,000 years ago, "natural selection has almost become irrelevant" to us, the influential Harvard paleontologist Stephen Jay Gould proclaimed. "There have been no biological changes. Everything we've called culture and civilization we've built with the same body and brain." This view has become so entrenched that it is practically doctrine. Even the founders of evolutionary psychology, Leda Cosmides and John Tooby, signed on to the notion that our brains were mostly sculpted during the long period when we were hunter-gatherers and have changed little since. "Our modern skulls house a Stone Age mind," they wrote in a background piece on the Center for Evolutionary Psychology at the University of California at Santa Barbara.

So to suggest that humans have undergone an evolutionary makeover from Stone Age times to the present is nothing short of blasphemous. Yet a team of researchers has done just that. They find an abundance of recent adaptive mutations etched in the human genome; even more shocking, these mutations seem to be piling up faster and ever faster, like an avalanche. Over the past 10,000 years, their data show, human evolution has occurred a hundred times more quickly than in any other period in our species' history.

The new genetic adaptations, some 2,000 in total, are not limited to the well-recognized differences among ethnic groups in superficial traits such as skin and eye color. The mutations relate to the brain, the digestive system, life span, immunity to pathogens, sperm production, and bones—in short, virtually every aspect of our

functioning.

Many of these DNA variants are unique to their continent of origin, with provocative implications. “It is likely that human races are evolving away from each other,” says University of Utah anthropologist Henry Harpending, who coauthored a major paper on recent human evolution. “We are getting less alike, not merging into a single mixed humanity.”

Harpending theorizes that the attitudes and customs that distinguish today’s humans from those of the past may be more than just cultural, as historians have widely assumed. “We aren’t the same as people even a thousand or two thousand years ago,” he says. “Almost every trait you look at is under strong genetic influence.”

Not surprisingly, the new findings have raised hackles. Some scientists are alarmed by claims of ethnic differences in temperament and intelligence, fearing that they will inflame racial sensitivities. Other researchers point to limitations in the data. Yet even skeptics now admit that some human traits, at least, are evolving rapidly, challenging yesterday’s hallowed beliefs.

A BONE TO PICK Bones don’t lie. John Hawks of the University of Wisconsin at Madison likes evidence he can put his hands on, so he takes me on a tour of the university’s bone laboratory. There, the energetic 36-year-old anthropologist unlocks a glass case and begins arranging human skulls and other skeletal artifacts—some genuine fossils, others high-quality reproductions—on a counter according to their age. Gesturing toward these relics, which span the past 35,000 years, Hawks says, “You don’t have to look hard to see that teeth are getting smaller, skull size is shrinking, stature is getting smaller.”

Anthropologist John Hawks collects skull samples from humans around the world in the bone lab at the University of Wisconsin at Madison. Image courtesy of John Hawks

These overriding trends are similar in many parts of the world, but other changes, especially over the past 10,000 years, are distinct to specific ethnic groups. “These variations are well known to forensic anthropologists,” Hawks says as he points them out: In Europeans, the cheekbones slant backward, the eye sockets are shaped like aviator glasses, and the nose bridge is high. Asians have

cheekbones facing more forward, very round orbits, and a very low nose bridge. Australians have thicker skulls and the biggest teeth, on average, of any population today. “It beats me how leading biologists could look at the fossil record and conclude that human evolution came to a standstill 50,000 years ago,” Hawks says.

By his account, Hawks’s theory of accelerated human evolution owes its genesis to what he could see with his own eyes. But his radical view was also influenced by newly emerging genetic data. Thanks to stunning advances in sequencing and deciphering DNA in recent years, scientists had begun uncovering, one by one, genes that boost evolutionary fitness. These variants, which emerged after the Stone Age, seemed to help populations better combat infectious organisms, survive frigid temperatures, or otherwise adapt to local conditions. And they were popping up with surprising frequency.

Taken together, the skeletal and genetic evidence convinced Hawks that the ruling “static” view of recent human evolution was not only wrong but also quite possibly the opposite of the truth. He discussed his ideas with Harpending, his former postdoc adviser at the University of Utah, and Gregory Cochran, a physicist and adjunct professor of anthropology there. They both agreed with Hawks’s interpretation. But why, they wondered, might evolution be picking up speed? What could be fueling the trend?

Then one day, as Hawks and Cochran mulled over the matter in a phone conversation, inspiration struck. “At exactly the same moment, both of us realized, gee, there’s a lot more people on the planet in recent times,” Hawks recalls. “In a large population you don’t have to wait so long for the rare mutation that boosts brain function or does something else desirable.”

The three scientists reviewed the demographic data. Ten thousand years ago, there were fewer than 10 million people on earth. That figure soared to 200 million by the time of the Roman Empire. Since around 1500 the global population has been rising exponentially, with the total now surpassing 6.7 billion. Since mutations are the fodder on which natural selection acts, it stands to reason that evolution might happen more quickly as our numbers surge. “What we were proposing was nothing new to animal breeders of the 19th century,” Cochran notes. “Darwin himself emphasized the

importance of maintaining a large herd for selecting favorable traits."

The logic behind the notion was undeniably simple, but at first glance it seemed counterintuitive. The genomes of any two individuals on the planet are more than 99.5 percent the same. Put another way, less than 0.5 percent of our DNA varies across the globe. That is often taken to mean that we have not evolved much recently, Cochran says, "but keep in mind that the human and chimp genomes differ by only about 1 to 2 percent—and nobody would call that a minor difference. None of this conflicts with the idea that human evolution might be accelerating."

CULTURE SHOCK If their hunch was correct, the scientists wondered a few years back, how could they prove it? As it turned out, it was an opportune time to pose that question.

For decades theories about human evolution had proliferated despite the absence of much, if any, hard evidence. But now there were finally human genetic data banks large enough to allow the scientists to put their assumptions to the test. One of these, the International Haplotype Map, cataloged differences in DNA collected from 270 people of Japanese, Han Chinese, Nigerian, and northern European descent. Moreover, Harpending knew two geneticists—Robert Moyzis of the University of California at Irvine, and Eric Wang of Veracyte Inc. in South San Francisco—who were at the forefront of developing new computational methods for mining this data to estimate the rate of evolution. Harpending contacted them to see if they would be willing to collaborate on a study.

The West Coast scientists were intrigued. On the basis of their own preliminary data, they, too, suspected that the pace of human evolution was accelerating. But they had arrived at the same crossroads by a different route. "We were focused on cultural shifts as a prime driving force of our evolution," Moyzis says. As he explains it, an exceptional period in the history of our species occurred about 50,000 years ago. Humans were pouring forth from Africa and fanning out across the globe, eventually taking up residence in niches as diverse as the Arctic Circle, the rain forests of the Amazon, the foothills of the Himalayas, and the Australian outback. Improvements in clothing, shelter, and hunting techniques

paved the way for this expansion.

Experts agree on that much but then part ways. These innovations, prominent evolutionary theorists insist, insulated us from the relentless winnowing of natural selection, thereby freeing us from the Darwinian rat race. But Moyzis and Wang looked at the same developments and came to the opposite conclusion. In our far-flung domains, they point out, humans presumably encountered starkly different selective forces as they adjusted to novel foods, predators, climates, and terrains. And as we became more innovative, the pressure to change only intensified. “If you’re a human, what is your environment but culture?” Moyzis asks. “The faster our ingenuity alters our habitat, the quicker we have to adapt in response.”

As for the role of population size in spurring our evolution, he and Wang had not given it much thought, but they saw the idea as complementary to their own view, since cultural innovations allowed more people to survive. So when Harpending’s group came calling, Moyzis says, “we were happy to combine ideas and work together.”

To study natural selection, the team combed the International Haplotype Map for long stretches of DNA flanked by a single nucleotide polymorphism (SNP, or “snip”)—that is, an altered base, or “letter,” in the genetic alphabet. When the exact same genetic block is present in at least 20 percent of a population, according to the scientists, it indicates that something about that block has conferred a survival advantage; otherwise, it would not have become so prevalent. Because genes are reshuffled with each generation, Moyzis adds, the presence of large unchanged blocks of DNA means they were probably inherited recently. In the parlance of scientists, it is “a signature of natural selection.”

Scanning genomes in the haplotype map for these clues, the researchers discovered that 7 percent of human genes fit the profile of a recent adaptation, with most of the change happening from 40,000 years ago to the present. As predicted, these apparent adaptations occurred at a rate that jumped almost exponentially in prevalence as the human population exploded. To rule out the prevailing view—that our evolution has proceeded at a steady rate all along—the scientists ran an additional check. They performed a computer simulation to see what would have happened if humans had evolved at modern rates ever since we diverged from

chimpanzees 6 million years ago. The steady-state test led to a nonsensical result: The difference between the two species today would be 160 times greater than it actually is. To Moyzis and the others, the results confirmed that human evolution had only recently hit the accelerator.

MORPHING AT HIGH SPEED All of these findings mesh beautifully with the notion that cultural and demographic shifts sparked our transformation. Our exodus out of Africa, for example, paved the way for one of the most obvious markers of race, skin hue. As scientists widely recognize, paler complexions are a genetic adjustment to low light: People with dark skin have trouble manufacturing vitamin D from ultraviolet radiation in northern latitudes, which makes them more susceptible to serious bone deformities. Consequently, Europeans and Asians over the last 20,000 years evolved lighter skin through two dozen different mutations that decrease production of the skin pigment melanin.

Similarly, the gene for blue eyes codes for paler skin coloring in many vertebrates and hence might have piggybacked along with lighter skin. Clearly something made blue eyes evolutionarily advantageous in some environments. “No one on earth had blue eyes 10,000 years ago,” Hawks says.

The transition to an agrarian existence after hundreds of thousands of years of hunting and gathering was another key catalyst of evolution. Once people began keeping cattle herds, for example, it became an advantage to derive nutrient calories from milk throughout life rather than only as an infant or toddler suckling at its mother’s breast. A mutation that arose about 8,000 years ago in northern Europe, Hawks says, allowed adults to digest lactose (the main sugar in milk), and it propagated rapidly, allowing the rise of the modern dairy industry. Today the gene for lactose digestion is present in 80 percent of Europeans but in just 20 percent of Asians and Africans.

Agriculture may have opened up other pathways for evolution by supporting an ever-growing population that eventually began to congregate in the first cities. In crowded, filthy quarters, pathogens spread like wildfire. Suddenly there were epidemics of smallpox, cholera, typhus, and malaria, diseases unknown to hunter-gatherers, and so began an evolutionary arms race to fend off the

assault through superior immunity.

“The clearest example of that is malaria,” Hawks says. “The disease is about 35,000 years old, with the most lethal form of it just 5,000 years old.” Yet in sub-Saharan Africa and other regions where it is endemic, “people have already developed 25 new genes that protect against malaria, including the Duffy blood type, an entirely new blood group,” he notes. More recently, HIV resistance has appeared due to a genetic mutation now found in 10 percent of Europeans. Scientists speculate that the variant may have originally evolved as a protection against smallpox.

Paralleling the constant war against pathogens, human sperm may also be evolving at high speed, driven by the race to get to the egg before another man’s sperm. “It could be that cities create more sexual partners, which means fiercer competition among males,” Hawks says. Because sperm can fertilize an egg up to 24 hours after being ejaculated in the vagina, a woman who copulates with two or more partners in close succession is setting up the very conditions that pit one man’s sperm against another’s. Hawks infers that “sperm today is very different from sperm even 5,000 years ago.” Newly selected mutations in genes controlling sperm production show up in every ethnic group he and his team have studied; those genes may affect characteristics including abundance, motility, and viability. The selection for “super sperm,” Hawks says, provides further corroboration that our species is not particularly monogamous—a view widely shared by other anthropologists.

At the other end of the human life span, “genes that help us live longer get selected,” Hawks reports. This may seem counterintuitive, since evolutionary biologists long assumed that the elderly do not contribute to the gene pool and hence are invisible to natural selection. But as studies of the Hadza people of Tanzania and other groups suggest, children doted on by their grandmothers—receiving extra provisions and care—are more likely to survive and pass on their grandmothers’ genes for longevity. (Grandfathers were less involved with their grandchildren in the cultures studied, so the phenomenon is known as the “grandmother effect.”) Old men can also pass on their genes by mating with younger women.

As agriculture became established and started creating a reliable

food supply, Hawks says, more men and women would have begun living into their forties and beyond—jump-starting the selection pressure for increased life span. In support of that claim, Moyzis is currently performing a genetic analysis of men and women in their nineties who are of European ancestry. He has traced many early-onset forms of cancer, heart disease, and Alzheimer's to older human gene variants. "The idea is that people with more modern variants tend to have greater resistance to these chronic illnesses of old age and should be overrepresented in the age 90-plus population," Moyzis says.

EVOLUTION AND THE BRAIN Perhaps the most incendiary aspect of the fast-evolution research is evidence that the brain may be evolving just as quickly as the rest of the body. Some genes that appear to have been recently selected, Moyzis and his collaborators suggest, influence the function and development of the brain. Other fast-changing genes—roughly 100—are associated with neurotransmitters, including serotonin (a mood regulator), glutamate (involved in general arousal), and dopamine (which regulates attention). According to estimates, fully 40 percent of these neurotransmitter genes seem to have been selected in the past 50,000 years, with the majority emerging in just the past 10,000 years.

Addressing the hot-potato question—What might these changes signify?—Moyzis and Wang theorize that natural selection probably favored different abilities and dispositions as modern groups adapted to the increasingly complex social order ushered in by the first human settlements.

When people in hunter-gatherer communities have a conflict, Moyzis reports, usually one of them will just walk away. "There is a great deal of fluidity in these societies," he says, "so it's easy to join another group." But with the establishment of the first farming communities, we put down roots figuratively as well as literally. "You can't just walk away," Moyzis notes, a fact that would have created selection pressure to revise the mechanisms regulating aggression, such as the glutamate pathways involved in arousal. "When you domesticate animals, you tend to change genes in that system," he says.

The rise of settlements also promoted the breakdown of labor into

specialized jobs. That, coupled with food surpluses from farming, led to systems of trade and the need to track the flow of resources, which in turn could have selected for individuals with specific cognitive strengths. “Mathematical ability is very important when it comes to keeping track of crops and bartering,” Wang says. “Certainly your working memory has to be better. You have to remember who owes you what.” The researchers point to China’s Mandarin system, a method of screening individuals for positions as tax collectors and other government administrators. For nearly 2,000 years, starting in A.D. 141, the sons of a broad cross section of Chinese society, including peasants and tradesmen, took the equivalent of standardized tests. “Those who did well on them would get a good job in the civil service and oftentimes had multiple wives, while the other sons remained in a rice field,” Moyzis says. “Probably for thousands of years in some cultures, certain kinds of intellectual ability may have been tied to reproductive success.”

Harpending and Cochran had previously—and controversially—marshaled similar evidence to explain why Ashkenazi Jews (those of northern European descent) are overrepresented among world chess masters, Nobel laureates, and those who score above 140 on IQ tests. In a 2005 article in the Journal of Biosocial Science, the scientists attributed Ashkenazis’ intellectual distinction to a religious and cultural environment that blocked them from working as farm laborers in central and northern Europe for almost a millennium, starting around A.D. 800. As a result, these Jews took jobs as moneylenders and financial administrators of estates. To make a profit, Harpending says, “they had to be good at evaluating properties and market risks, all the while dodging persecution.” Those who prospered in these mentally demanding and hostile environments, the researchers posit, would have left behind the most offspring. Critics note that the association between wealth and intelligence in this interpretation is circumstantial, however.

Stronger evidence that natural selection has continued to shape the brain in recent epochs comes from studies of DRD4, a mutation in a neurotransmitter receptor that Moyzis, Wang, and many others have linked to attention-deficit/hyperactivity disorder (ADHD). Children diagnosed with ADHD are twice as likely to carry the variant gene as those without the diagnosis. DRD4 makes a

receptor in the brain less effective in bonding to dopamine, which might explain why Ritalin, which increases the amount of dopamine in the space between neurons, is often helpful in treating the problem.

Sequencing studies suggest that the DRD4 mutation arose 50,000 years ago, just as humans were spreading out of Africa. Its prevalence tends to increase the farther a population is from Africa, leading some investigators to dub it “the migratory gene.” At least one allele (or copy of the gene) is carried by 80 percent of some South American populations. In contrast, the allele is present in 40 percent of indigenous populations living farther north in the Americas and in just 20 percent of Europeans and Africans. Children with the mutation tend to be more restless than other youngsters and to score higher on tests of novelty-seeking and risk-taking, all traits that might have pushed those with the variant to explore new frontiers.

In the context of a modern classroom, it may be hard to understand why kids who appear distractible and disruptive might have a survival advantage. But research shows people with DRD4 do not differ in intelligence from national norms; if anything, they may on average be smarter. Moreover, behavior that may seem like a drawback today may not have been so in ancient environments. When broaching foreign terrain filled with unknown predators, “having the trait of focusing on multiple directions might have been a good thing,” Wang says. “People focused in one direction might get eaten.”

NOT SO FAST Despite all these clues that human evolution has continued and accelerated into modern times, many evolutionary biologists remain deeply skeptical of the claims. Their resistance comes from several directions.

Some independent experts caution that the tools for studying the human genome remain in their infancy, and reliably detecting genomic regions that have been actively selected is a challenging problem. The hypothesis that human evolution is accelerating “all rests on being able to identify recent areas of the genome under natural selection fairly accurately,” says human geneticist Jonathan Pritchard of the University of Chicago. And that, he warns, is tricky, involving many different assumptions (about population sizes on

different continents, for instance) in the poorly documented period before recorded history.

Given such uncertainties, researchers are more likely to be persuaded that a mutation has been recently selected if they understand its function and if its rise in prevalence meshes well with known human migratory routes. Genetic variants fitting that description include those coding for lighter skin coloring, resistance to diseases such as malaria, and metabolic changes related to the digestion of novel foods. There is broad consensus that these represent genuine examples of recent adaptations.

Question marks surround many other recent genetic changes. We know almost nothing about most regions of the genome that have been identified as potential targets of natural selection, observes Sarah Tishkoff, a geneticist at the University of Pennsylvania School of Medicine. Until scientists understand more of the landscape of the human genome, she says, she will have a hard time believing that adaptive genetic differences between ethnic groups have mushroomed over the past 20,000 years. She is particularly wary of claims that selective pressures recently played a role in shaping different cognitive abilities and temperaments among ethnic groups. “We have no strong evidence of that,” Tishkoff says.

Francis Collins, who until last year headed the National Human Genome Research Institute at the National Institutes of Health, concurs. “This is not a place to idly speculate about possibilities,” he says. “When it comes to brain functioning, let’s be honest: That is a tinderbox of possible explosive reactions based upon a very unpretty history of discrimination and of demagogues using information that they claimed came from biology in order to put down some groups that they didn’t like.” Even when it comes to the ADHD connection, Collins is a skeptic. “I want to see DRD4 replicated by independent investigators on an independent sample of children,” he says.

In some circles, Moyzis says, to suggest that natural selection is acting on the human brain is tantamount to heresy—an incredible hypothesis that demands extraordinary proof. Harpending, Cochran, and their collaborators are mystified as to what it is that makes their theory so incredible. “I would turn that statement on its

head," Moyzis says. "The extraordinary claim is that evolution somehow stopped once we developed culture." Cochran says, "You're allowed to change, but only if it's below the neck. Many people think the brain has to be immune to natural selection; if it isn't, they don't want to hear it."

Harvard University evolutionary biologist Pardis Sebati defends that view. "The immune system and skin interact directly with the outside world," she says. "They are our first line of defense." Based on the current evidence, she concludes, sunlight and pathogens were among the strongest selective forces, and skin and the immune system underwent the most dramatic change; evolutionary pressures on the brain are not nearly as clear-cut. As Harvard geneticist David Altshuler wrote in response to one of Sebati's articles, "It's reassuring that differences between the races seem to be mostly skin deep."

The "reassuring" quality of that belief makes those in the opposing camp wonder if some of the logic of skeptics is tinged with wishful thinking. Harvard's Steven Pinker, the celebrated author of The Blank Slate and an expert on the evolution of language and the mind, addressed that point in an interview in New Scientistmagazine: "People, including me, would rather believe that significant human biological evolution stopped between 50,000 and 100,000 years ago, before the races diverged, which would ensure that racial and ethnic groups are biologically equivalent."

Many scientists apparently worry that proof of divergent brain evolution could be so racially polarizing that we, as a society, would almost be better off in the dark. Hawks responds that the best safeguard against bigotry is educating the public. He thinks we understand enough about human genetics to know that the notion of racial superiority is absurd. Intelligence, he argues, is not a single trait but a vast suite of abilities, and each ancestral environment may have favored a different set of talents. What is sorely needed, he says, is "an ecological framework" to interpret the results. "Groups are best adapted to their own environment, which eliminates the question of superiority." Even he concedes, though, that communicating the nuances will be no easy task.

"Whatever we find," Wang says, "it would never be justification for abandoning the egalitarian value that all individuals, regardless of

their ethnicity, are deserving of the same rights and opportunities." Moyzis expands on that line of reasoning, putting a sunny spin on the group's findings. "It would be boring if all the races were fundamentally the same," he argues. "It's exciting to think that they bring different strengths and talents to the table. That is part of what makes melting-pot cultures like our own so invigorating and creative."

Of course, in melting-pot cultures all kinds of ethnic groups intermingle freely, and the children who result literally meld our DNA together. Even if those groups were diverging, international travel is now causing the diversity to get lost in the genetic reshuffling. "That's the ultimate irony," Moyzis says. "By the time we finally settle this debate, we'll all be such a mixture of genes that we won't care."