WHAT WILL BECOME OF *HOMO SAPIENS*?

Contrary to popular belief, humans continue to evolve. Our bodies and brains are not the same as our ancestors' were—or as our descendants' will be • • • BY PETER WARD

When you ask for opinions about what future humans might look like, you typically get one of two answers. Some people trot out the old science-fiction vision of a big-brained human with a high forehead and higher intellect. Others say humans are no longer evolving physically—that technology has put an end to the brutal logic of natural selection and that evolution is now purely cultural.

The big-brain vision has no real scientific basis. The fossil record of skull sizes over the past several thousand generations shows that our days of rapid increase in brain size are long over. Accordingly, most scientists a few years ago would have taken the view that human physical evolution has ceased. But DNA techniques, which probe genomes both present and past, have unleashed a revolution in studying evolution; they tell a different story. Not only has *Homo sapiens* been doing some major genetic reshuffling since our species formed, but the rate of human evolution may, if anything, have increased. In common with other organisms, we underwent the most dramatic changes to our body shape when our species first appeared, but we continue to show genetically induced changes to our physiology and perhaps to our behavior as well. Until fairly recently in our history, human races in various parts of the world were becoming more rather than less distinct. Even today the conditions of modern life could be driving changes to genes for certain behavioral traits.

If giant brains are not in store for us, then what is? Will we become larger or smaller, smarter or dumber? How will the emergence of new diseases and the rise in global temperature shape us? Will a new human species arise one day? Or does the future evolution of humanity lie not within our genes but within our technology, as we augment our brains and bodies with silicon and steel? Are we but the builders of the next dominant intelligence on the earth—the machines?

KEY CONCEPTS

- People commonly assume that our species has evolved very little since prehistoric times. Yet new studies using genetic information from populations around the globe suggest that the pace of human evolution increased with the advent of agriculture and cities.
- If we are still evolving, what might our species look like in a millennium should we survive whatever environmental and social surprises are in store for us? Speculation ranges from the hopeful to the dystopian.

—The Editors

The Far and Recent Past

Tracking human evolution used to be the province solely of paleontologists, those of us who study fossil bones from the ancient past. The human family, called the Hominidae, goes back at least seven million years to the appearance of a small proto-human called *Sahelanthropus tchadensis*. Since then, our family has had a still disputed, but rather diverse, number of new species in it—as many as nine that we know of and others surely still hidden in the notoriously poor hominid fossil record. Because early human skeletons rarely made it into sedimentary rocks before they were scavenged, this estimate changes from year to year as new discoveries and new interpretations of past bones make their way into print [see "Once We Were Not Alone," by Ian Tattersall; Scientific American, January 2000, and "An Ancestor to Call Our Own," by Kate

NESSIM HIGSON (*photoillustration*); KEVIN SUMMERS *Getty Images* (*flower*); PAUL TAYLOR *Getty Images* (*hand*); RON LEVINE *Getty Images* (*girl*); PHOTODISC *Getty Images* (*brain*); iSTOCKPHOTO.COM (*skull and egg*)

BEYOND *HOMO SAPIENS*

Our lineage has produced new species in the past. What about the future? Speciation requires an isolating mechanism of some kind. The most common is geographic isolation, where a small population gets cut off from the larger gene pool. The very size and interconnectedness of humanity make this possibility low under present conditions, but here are some ways to bring it about:

Setting up human colonies on distant worlds.

Losing or voluntarily discarding the technology that allows the global interchange of our genes.

Breaking into isolated groups after an apocalypse such as a large asteroid hitting the earth.

Engaging in genetic engineering.

THE AUTHOR

Peter Ward has been active in paleontology, biology and astrobiology for more than 30 years. He led the University of Washington node of the NASA Astrobiology Institute, a team of more than 40 scientists and students, from 2001 to 2006. Ward is especially known as an expert on mass extinctions and the role of extraterrestrial impacts on the earth. He and his 11-year-old son recently built a reconstruction of the late Cretaceous world on a large model-train layout, replete with dinosaurs to scale, and can now attest that the extinction of the dinosaurs was caused by speeding locomotives.

Wong; Scientific American, January 2003].

Each new species evolved when a small group of hominids somehow became separated from the larger population for many generations and then found itself in novel environmental conditions favoring a different set of adaptations. Cut off from kin, the small population went its own genetic route and eventually its members could no longer successfully reproduce with the parent population.

The fossil record tells us that the oldest member of our own species lived 195,000 years ago in what is now Ethiopia. From there it spread out across the globe. By 10,000 years ago modern humans had successfully colonized each of the continents save Antarctica, and adaptations to these many locales (among other evolutionary forces) led to what we loosely call races. Groups living in different places evidently retained just enough connections with one another to avoid evolving into separate species. With the globe fairly well covered, one might expect that the time for evolving was pretty much finished.

But that turns out not to be the case. In a study published a year ago Henry C. Harpending of the University of Utah, John Hawks of the University of Wisconsin–Madison and their colleagues analyzed data from the international haplotype map of the human genome [see "Traces of a Distant Past," by Gary Stix; Scientific American, July 2008]. They focused on genetic markers in 270 people from four groups: Han Chinese, Japanese, Yoruba and northern Europeans. They found that at least 7 percent of human genes underwent evolution as recently as 5,000 years ago. Much of the change involved adaptations to particular environments, both natural and human-shaped. For example, few people in China and Africa can digest fresh milk into adulthood, whereas almost everyone in Sweden and Denmark can. This ability presumably arose as an adaptation to dairy farming.

Another study by Pardis C. Sabeti of Harvard University and her colleagues used huge data sets of genetic variation to look for signs of natural selection across the human genome. More than 300 regions on the genome showed evidence of recent changes that improved people's chance of surviving and reproducing. Examples included resistance to one of Africa's great scourges, the virus causing Lassa fever; partial resistance to other diseases, such as malaria, among some African populations; changes in skin pigmentation and development of hair follicles among Asians; and the evolution of lighter skin and blue eyes in northern Europe.

Harpending and Hawks's team estimated that over the past 10,000 years humans have evolved as much as 100 times faster than at any other time since the split of the earliest hominid from the ancestors of modern chimpanzees. The team attributed the quickening pace to the variety of environments humans moved into and the changes in living conditions brought about by agriculture and cities. It was not farming per se or the changes in the landscape that conversion of wild habitat to tamed fields brought about but the often lethal combination of poor sanitation, novel diet and emerging diseases (from other humans as well as domesticated animals). Although some researchers have expressed reservations about these estimates, the basic point seems clear: humans are first-class evolvers.

Unnatural Selection

During the past century, our species' circumstances have again changed. The geographic isolation of different groups has been broached by the ease of transportation and the dismantling of social barriers that once kept racial groups apart. Never before has the human gene pool had such widespread mixing of what were heretofore entirely separated local populations of our species. In fact, the mobility of humanity might be bringing about the homogenization of our species. At the same time, natural selection in our species is being thwarted by our technology and our medicines. In most parts of the globe, babies no longer die in large numbers. People with genetic damage that was once fatal now live and have children. Natural predators no longer affect the rules of survival.

Steve Jones of University College London has argued that human evolution has essentially ceased. At a Royal Society of Edinburgh debate in 2002 entitled "Is Evolution Over?" he said: "Things have simply stopped getting better, or worse, for our species. If you want to know what Utopia is like, just look around—this is it." Jones suggested that, at least in the developed world, almost everyone has the opportunity to reach reproductive age, and the poor and rich have an equal chance of having children. Inherited disease resistance—say, to HIV—may still confer a survival advantage, but culture, rather than genetic inheritance, is now the deciding factor in whether people live or die. In short, evolution may now be memetic—involving ideas—rather than genetic [see "The Power of Memes," by Susan Blackmore; Scientific American, October 2000].

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Another point of view is that genetic evolution continues to occur even today, but in reverse. Certain characteristics of modern life may drive evolutionary change that does not make us fitter for survival—or that even makes us less fit. Innumerable college students have noticed one potential way that such "inadaptive" evolution could happen: they put off reproduction while many of their high school classmates who did not make the grade started having babies right away. If less intelligent parents have more kids, then intelligence is a Darwinian liability in today's world, and average intelligence might evolve downward.

Such arguments have a long and contentious history. One of the many counterarguments is that human intelligence is made up of many different abilities encoded by a large number of genes. It thus has a low degree of heritability, the rate at which one generation passes the trait to the next. Natural selection acts only on heritable traits. Researchers actively debate just how heritable intelligence is [see "The Search for Intelligence," by Carl Zimmer; SCIENTIFIC AMERICAN, October 2008], but they have found no sign that average intelligence is in fact decreasing.

Even if intelligence is not at risk, some scientists speculate that other, more heritable traits could be accumulating in the human species and that these traits are anything but good for us. For instance, behavior disorders such as Tourette's syndrome and attention-deficit hyperactivity disorder (ADHD) may, unlike intelligence, be encoded by but a few genes, in which case their heritability could be very high. If these disorders increase one's chance of having children, they could become ever more prevalent with each generation. David Comings, a specialist in these two diseases, has argued in scientific papers and a 1996 book that these conditions are more common than they used to be and that evolution might be one reason: women with these syndromes are less likely to attend college and thus tend to have more children than those who do not. But other researchers have brought forward serious concerns about Comings's methodology. It is not clear whether the incidence of Tourette's and ADHD is, in fact, increasing at all. Research into these areas is also made more difficult because of the perceived social stigma that many of these afflictions attach to their carriers.

Although these particular examples do not pass scientific muster, the basic line of reasoning is plausible. We tend to think of evolution as something involving structural modification, yet it can and does affect things invisible from the outside—behavior. Many people carry the genes making them susceptible to alcoholism, drug addiction and other problems. Most do not succumb, because genes are not destiny; their effect depends on our environment. But others do succumb, and their problems may affect whether they survive and how many children they have. These changes in fertility are enough for natural selection to act on. Much of humanity's future evolution may involve new sets of behaviors that spread in response to changing social and environmental conditions. Of course, humans differ from other species in that we do not have to accept this Darwinian logic passively.

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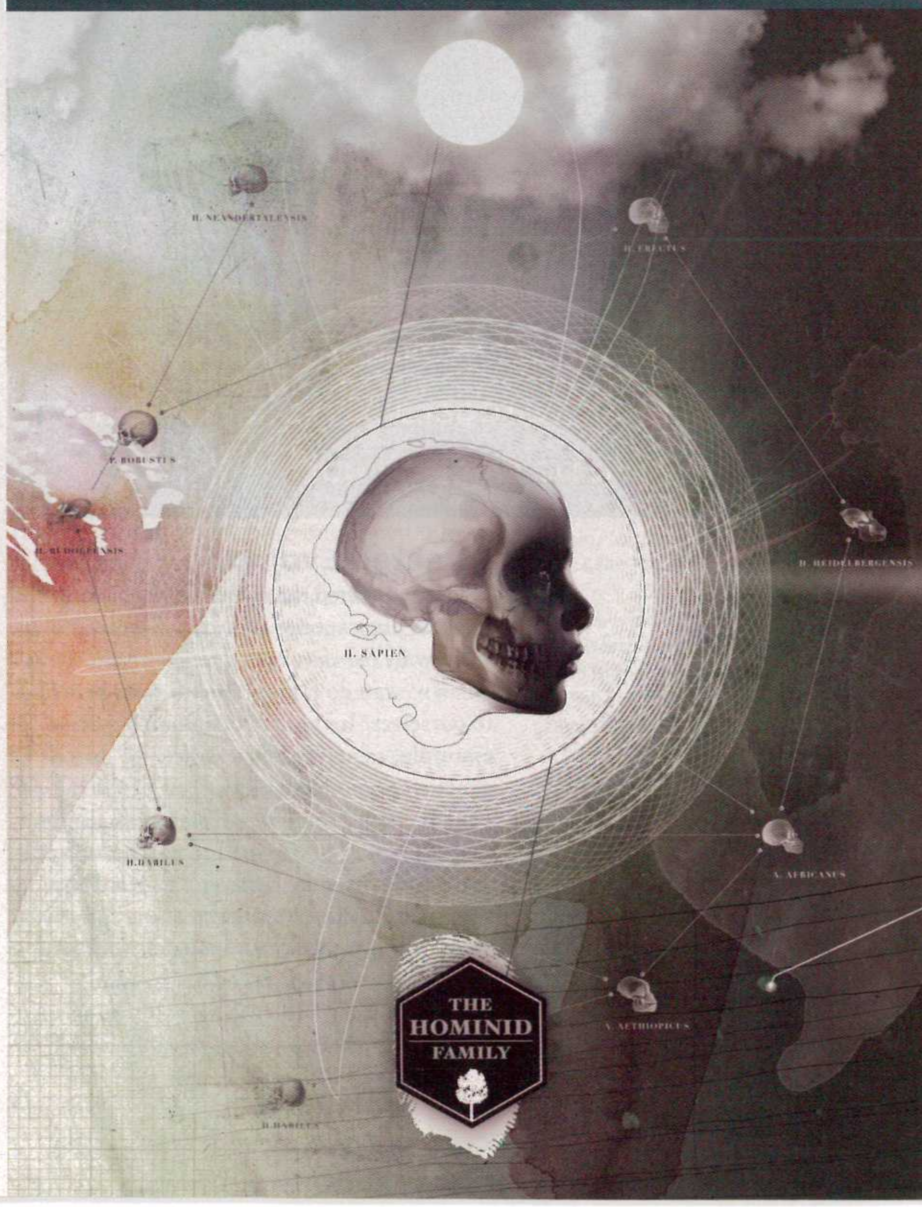

NESSIM HIGSON (*photoillustration*); ISTOCKPHOTO.COM (*skull and boy's head*)

NESSIM HIGSON (*photoillustration*); AMANA PRODUCTIONS *Getty Images* (woman)

If machine efficiency became the new measure of evolutionary fitness, much of what we regard as quintessentially human would be weeded out.

Directed Evolution

We have directed the evolution of so many animal and plant species. Why not direct our own? Why wait for natural selection to do the job when we can do it faster and in ways beneficial to ourselves? In the area of human behavior, for example, geneticists are tracking down the genetic components not just of problems and disorders but also of overall disposition and various aspects of sexuality and competitiveness, many of which may be at least partially heritable. Over time, elaborate screening for genetic makeup may become commonplace, and people will be offered drugs based on the results.

The next step will be to actually change people's genes. That could conceivably be done in two ways: by changing genes in the relevant organ only (gene therapy) or by altering the entire genome of an individual (what is known as germ-line therapy). Researchers are still struggling with the limited goal of gene therapy to cure disease. But if they can ever pull off germ-line therapy, it will help not only the individual in question but also his or her children. The major obstacle to genetic engineering in humans will be the sheer complexity of the genome. Genes usually perform more than one function; conversely, functions are usually encoded by more than one gene. Because of this property, known as pleiotropy, tinkering with one gene can have unintended consequences.

Why try at all, then? The pressure to change genes will probably come from parents wanting to guarantee their child is a boy or a girl; to endow their children with beauty, intelligence, musical talent or a sweet nature; or to try to ensure that they are not helplessly disposed to become mean-spirited, depressed, hyperactive or even criminal. The motives are there, and they are very strong. Just as the push by parents to genetically enhance their children could be socially irresistible, so, too, would be an assault on human aging. Many recent studies suggest that aging is not so much a simple wearing down of body parts as it is a programmed decay, much of it genetically controlled. If so, the next century of genetic research could unlock numerous genes controlling many aspects of aging. Those genes could be manipulated.

Assuming that it does become practical to change our genes, how will that affect the future evolution of humanity? Probably a great deal. Suppose parents alter their unborn children to enhance their intelligence, looks and longevity. If the kids are as smart as they are long-lived—an IQ of 150 and a lifespan of 150 years—they could have more children and accumulate more wealth than the rest of us. Socially they will probably be drawn to others of their kind. With some kind of self-imposed geographic or social segregation, their genes might drift and eventually differentiate as a new species. One day, then, we will have it in our power to bring a new human species into this world. Whether we choose to follow such a path is for our descendants to decide.

The Borg Route

Even less predictable than our use of genetic manipulation is our manipulation of machines—or they of us. Is the ultimate evolution of our species one of symbiosis with machines, a human-machine synthesis? Many writers have predicted that we might link our bodies with robots or upload our minds into computers. In fact, we are already dependent on machines. As much as we build them to meet human needs, we have structured our own lives and behavior to meet theirs. As machines become ever more complex and interconnected, we will be forced to try to accommodate them. This view was starkly enunciated by George Dyson in his 1998 book *Darwin among the Machines:* "Everything that human beings are doing to make it easier to operate computer networks is at the same time, but for different reasons, making it easier for computer networks to operate human beings.... Darwinian evolution, in one of those paradoxes with which life abounds, may be a victim of its own success, unable to keep up with non-Darwinian processes that it has spawned."

Our technological prowess threatens to swamp the old ways that evolution works. Consider two different views of the future taken from an essay in 2004 by evolutionary philosopher Nick Bostrom of the University of Oxford. On the optimistic side, he wrote: "The big picture shows an overarching trend towards increasing levels of complexity, knowledge, consciousness, and coordinated goal-directed organization, a trend which, not to put too fine a point on it, we may label 'progress.' What we shall call the Panglossian view maintains that this past record of success gives us good grounds for thinking that evolution (whether biological, memetic or technological) will continue to lead in desirable directions."

Although the reference to "progress" surely causes the late evolutionary biologist Steven Jay Gould to spin in his grave, the point can be made. As Gould argued, fossils, including those from our own ancestors, tell us that evolutionary change is not a continuous thing; rather it occurs in fits and starts, and it is certainly not "progressive" or directional. Organisms get smaller as well as larger. But evolution has indeed shown at least one vector: toward increasing complexity. Perhaps that is the fate of future human evolution: greater complexity through some combination of anatomy, physiology or behavior. If we continue to adapt (and undertake some deft planetary engineering), there is no genetic or evolutionary reason that we could not still be around to watch the sun die. Unlike aging, extinction does not appear to be genetically programmed into any species.

The darker side is all too familiar. Bostrom (who must be a very unsettled man) offered a vision of how uploading our brains into computers could spell our doom. Advanced artificial intelligence could encapsulate the various components of human cognition and reassemble those components into something that is no longer human—and that would render us obsolete. Bostrom predicted the following course of events: "Some human individuals upload and make many copies of themselves. Meanwhile, there is gradual progress in neuroscience and artificial intelligence, and eventually it becomes possible to isolate individual cognitive modules and connect them up to modules from other uploaded minds.... Modules that conform to a common standard would be better able to communicate and cooperate with other modules and would therefore be economically more productive, creating a pressure for standardization.... There might be no niche for mental architectures of a human kind."

As if technological obsolescence were not disturbing enough, Bostrom concluded with an even more dreary possibility: if machine efficiency became the new measure of evolutionary fitness, much of what we regard as quintessentially human would be weeded out of our lineage. He wrote: "The extravagancies and fun that arguably give human life much of its meaning—humor, love, game-playing, art, sex, dancing, social conversation, philosophy, literature, scientific discovery, food and drink, friendship, parenting, sport—we have preferences and capabilities that make us engage in such activities, and these predispositions were adaptive in our species' evolutionary past; but what ground do we have for being confident that these or similar activities will continue to be adaptive in the future? Perhaps what will maximize fitness in the future will be nothing but nonstop high-intensity drudgery, work of a drab and repetitive nature, aimed at improving the eighth decimal of some economic output measure."

In short, humanity's future could take one of several routes, assuming we do not go extinct:

Stasis. We largely stay as we are now, with minor tweaks, mainly as races merge.

Speciation. A new human species evolves on either this planet or another.

Symbiosis with machines. Integration of machines and human brains produces a collective intelligence that may or may not retain the qualities we now recognize as human.

Quo vadis Homo futuris? ■

MORE TO EXPLORE

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