The New York Times
nytimes.com

June 26, 2007

Humans Have Spread Globally, and Evolved Locally

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Historians often assume that they need pay no attention to human evolution because the process ground to a halt in the distant past. That assumption is looking less and less secure in light of new findings based on decoding human DNA.

People have continued to evolve since leaving the ancestral homeland in northeastern Africa some 50,000 years ago, both through the random process known as genetic drift and through natural selection. The genome bears many fingerprints in places where natural selection has recently remolded the human clay, researchers have found, as people in the various continents adapted to new diseases, climates, diets and, perhaps, behavioral demands.

A striking feature of many of these changes is that they are local. The genes under selective pressure found in one continent-based population or race are mostly different from those that occur in the others. These genes so far make up a small fraction of all human genes.

A notable instance of recent natural selection is the emergence of lactose tolerance — the ability to digest lactose in adulthood — among the cattle-herding people of northern Europe some 5,000 years ago. Lactase, the enzyme that digests the principal sugar of milk, is usually switched off after weaning. But because of the great nutritional benefit for cattle herders of being able to digest lactose in adulthood, a genetic change that keeps the lactase gene switched on spread through the population.

Lactose tolerance is not confined to Europeans. Last year, Sarah Tishkoff of the University of Maryland and colleagues tested 43 ethnic groups in East Africa and found three separate mutations, all different from the European one, that keep the lactase gene switched on in adulthood. One of the mutations, found in peoples of Kenya and Tanzania, may have arisen as recently as 3,000 years ago.

That lactose tolerance has evolved independently four times is an instance of convergent evolution. Natural selection has used the different mutations available in European and East African populations to make each develop lactose tolerance. In Africa, those who carried the mutation were able to leave 10 times more progeny, creating a strong selective advantage.

Researchers studying other single genes have found evidence for recent evolutionary change in the genes that mediate conditions like skin color, resistance to malaria and salt retention.

The most striking instances of recent human evolution have emerged from a new kind of study, one in which the genome is scanned for evidence of selective pressures by looking at a few hundred thousand specific sites where variation is common.

Last year Benjamin Voight, Jonathan Pritchard and colleagues at the University of Chicago searched for

genes under natural selection in Africans, Europeans and East Asians. In each race, some 200 genes showed signals of selection, but without much overlap, suggesting that the populations on each continent were adapting to local challenges.

Another study, by Scott Williamson of Cornell University and colleagues, published in PLoS Genetics this month, found 100 genes under selection in Chinese, African-Americans and European-Americans.

In most cases, the source of selective pressure is unknown. But many genes associated with resistance to disease emerge from the scans, confirming that disease is a powerful selective force. Another category of genes under selective pressure covers those involved in metabolism, suggesting that people were responding to changes in diet, perhaps associated with the switch from hunting and gathering to agriculture.

Several genes involved in determining skin color have been under selective pressure in Europeans and East Asians. But Dr. Pritchard's study detected skin color genes only in Europeans, and Dr. Williamson found mostly genes selected in Chinese.

The reason for the difference is that Dr. Pritchard's statistical screen detects genetic variants that have become very common in a population but are not yet universal. Dr. Williamson's picks up variants that have already swept through a population and are possessed by almost everyone.

The findings suggest that Europeans and East Asians acquired their pale skin through different genetic routes and, in the case of Europeans, perhaps as recently as around 7,000 years ago.

Another puzzle is presented by selected genes involved in brain function, which occur in different populations and could presumably be responses to behavioral challenges encountered since people left the ancestral homeland in Africa.

But some genes have more than one role, and some of these brain-related genes could have been selected for other properties.

Two years ago, Bruce Lahn, a geneticist at the University of Chicago, reported finding signatures of selection in two brain-related genes of a type known as microcephalins, because when mutated, people are born with very small brains. Two of the microcephalins had come under selection in Europeans and one in Chinese, Dr. Lahn reported.

He suggested that the selected forms of the gene had helped improved cognitive capacity and that many other genes, yet to be identified, would turn out to have done the same in these and other populations.

Neither microcephalin gene turned up in Dr. Pritchard's or Dr. Williamson's list of selected genes, and other researchers have disputed Dr. Lahn's claims. Dr. Pritchard found that two other microcephalin genes were under selection, one in Africans and the other in Europeans and East Asians.

Even more strikingly, Dr. Williamson's group reported that a version of a gene called DAB1 had become universal in Chinese but not in other populations. DAB1 is involved in organizing the layers of cells in the cerebral cortex, the site of higher cognitive functions.

Variants of two genes involved in hearing have become universal, one in Chinese, the other in Europeans.

The emerging lists of selected human genes may open new insights into the interactions between history and genetics. “If we ask what are the most important evolutionary events of the last 5,000 years, they are cultural, like the spread of agriculture, or extinctions of populations through war or disease,” said Marcus Feldman, a population geneticist at Stanford. These cultural events are likely to have left deep marks in the human genome.

A genomic survey of world populations by Dr. Feldman, Noah Rosenberg and colleagues in 2002 showed that people clustered genetically on the basis of small differences in DNA into five groups that correspond to the five continent-based populations: Africans, Australian aborigines, East Asians, American Indians and Caucasians, a group that includes Europeans, Middle Easterners and people of the Indian subcontinent. The clusterings reflect “serial founder effects,” Dr. Feldman said, meaning that as people migrated around the world, each new population carried away just part of the genetic variation in the one it was derived from.

The new scans for selection show so far that the populations on each continent have evolved independently in some ways as they responded to local climates, diseases and, perhaps, behavioral situations.

The concept of race as having a biological basis is controversial, and most geneticists are reluctant to describe it that way. But some say the genetic clustering into continent-based groups does correspond roughly to the popular conception of racial groups.

“There are difficulties in where you put boundaries on the globe, but we know now there are enough genetic differences between people from different parts of the world that you can classify people in groups that correspond to popular notions of race,” Dr. Pritchard said.

David Reich, a population geneticist at the Harvard Medical School, said that the term “race” was scientifically inexact and that he preferred “ancestry.” Genetic tests of ancestry are now so precise, he said, that they can identify not just Europeans but can distinguish between northern and southern Europeans. Ancestry tests are used in trying to identify genes for disease risk by comparing patients with healthy people. People of different races are excluded in such studies. Their genetic differences would obscure the genetic difference between patients and unaffected people.

No one yet knows to what extent natural selection for local conditions may have forced the populations on each continent down different evolutionary tracks. But those tracks could turn out to be somewhat parallel. At least some of the evolutionary changes now emerging have clearly been convergent, meaning that natural selection has made use of the different mutations available in each population to accomplish the same adaptation.

This is the case with lactose tolerance in European and African peoples and with pale skin in East Asians and Europeans.