Anthropology

Human evolution and its future

Interview: Martin Thurau

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Whither human evolution? In the following interview, anthropologist Gisela Grupe and population geneticist Wolfgang Stephan highlight crucial stages in the evolution of our species Homo sapiens.

We want to talk about origins, the origins of the human race. So for a start, who were our ancestors, and how did we learn to walk upright?

Grupe: We belong to the ape family, a lineage which originated more than 15 million years ago, and from which the genera *Australopithecus* and *Homo* evolved. The ability to walk upright is only one of the traits that now distinguish us from contemporary great apes. About 40 other primate species are known to have walked on their hind-limbs, all of which are now extinct. So bipedalism is no guarantee of evolutionary success. A plethora of hypotheses has been proposed to account for human bipedalism, and many of them are implausible. Nutritional factors may have been decisive, as bipedalism enabled our ancestors to exploit foods that were less accessible to competitors.

And what accounts for the evolutionary success of the modern species *Homo sapiens* relative to its direct ancestors?

Grupe: The fact that *H. sapiens* happened to survive.

Happened to ...?

Grupe: That our lineage would escape extinction wasn't a foregone conclusion. Hominins underwent an adaptive radiation. A whole range of related species evolved, but only the line leading to *Homo erectus* and *H. sapiens* survived. And the distinctive traits that characterize these two hominins – such as a more complex brain structure with an enlarged cerebral cortex that provided the substrate for the subsequent evolution of a variety of cognitive abilities – emerged very early in primate evolution.

Where then did *Homo sapiens* come from?

Grupe: The oldest known fossil is from Africa and is 160,000 years old. Africa is the cradle of humanity; I don't believe that this conclusion will ever be overturned. It is supported by molecular biological analyses, such as molecular clock models, which are based on the insight that the number of fixed mutations in one lineage relative to another provides a measure of the time elapsed since the two diverged. The larger the number of differences between two variants, the older their last common ancestor must be.

Stephan: The molecular data show that we all share a common female ancestor, who lived in Africa well over 100,000 years ago, and from whom we inherited our mitochondria. Mitochondria are the intracellular organelles that supply the energy for metabolism, and they contain their own genome. Comparatively speaking, its DNA sequence is quite stable, which makes it suitable for tracing long periods of evolutionary history.

Out of Africa to conquer the globe: What prompted these migrations? Is *Wanderlust* part of human nature?

Grupe: The earliest migrations began about 2 million years ago, and took early man to Europe and Asia. Fossils from Dmanisi in Georgia date from 1.8 million years ago. Climatic conditions had changed and population pressure had grown. Then about 120,000 years ago, *H. sapiens* moved into the Arabian Peninsula and from there on to India and into the Near East. Anatomically modern humans only reached Europe much later.

Stephan: Analyses of genetic diversity among modern-day Africans enable us to estimate the population size 150,000 years ago and deduce how it has developed since then. These studies show that there were times when *H. sapiens* came close to extinction, and would have qualified for inclusion on any Red List of endangered species. Various estimates suggest that the total human population fell to 15,000 – and perhaps even much less, segmented into small, isolated groups. The environment had become much less benign, forcing the survivors to migrate. Population geneticists speak of a 'bottleneck effect'. The surviving genetic diversity was equivalent in size to the population of a small town like Pullach. And migratory movements gave rise to so-called founder effects. Each group that moved further took only a fraction of the genetic diversity present in its ancestral population with it, steadily

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reducing the amount of genetic variation available.

How did we as a species learn language? There are two competing accounts of the origin of language. One postulates that humans had developed the necessary anatomical and neurological adaptations 1.5 million years ago, and language slowly evolved thereafter – in parallel with a sense of social cognition, an impulse to share knowledge with others in the same environment. A second school of thought proposes that spoken language evolved quite suddenly only about 200,000 years ago and rapidly diffused to all human societies. Which alternative do you find more plausible?

Grupe: The first problem is what we mean by 'language'. Spoken language is not the only possible form of communication. There are sign languages, gestures – which we use in combination with speech. We also know of aboriginal populations that developed languages based on whistles or click sounds. The anatomical requirements for the enunciation of articulated speech were present very early in human evolution, as were – in rudimentary form – the brain areas that later played an important role in enabling the abstract reasoning needed for processing speech. But other conditions certainly had to be met before vocalized speech could emerge, and these may well have arisen relatively late in human evolution – which is not to say that sophisticated communication was impossible before that.

Many geneticists assign great weight to certain mutations in the gene *FOXP2*, arguing that these strongly favored development of the ability to articulate and process spoken language.

Stephan: *FOXP2* is often referred to as a 'language gene', which I think goes too far. It codes for a protein that acts as a transcription factor to regulate hundreds of genes in different cell types. It is found in many animal species – in apes, in zebrafish and zebra finches. The human version differs only slightly from the others but, according to the protagonists of the language-gene theory, the two mutations that distinguish it from the chimpanzee variant are crucial. These mutations permit more precise regulation of the neck, mouth and facial muscles, which improves breath control and articulation. Researchers have also shown that the human variant of *FOXP2* boosts learning ability in animal models. This they interpret as an indication of a greater capacity for abstraction, which is undoubtedly a prerequisite for the development of grammar. The *FOX2P* story also made waves because it seemed to represent a case of accelerated evolution, since a functionally important variant had apparently become fixed in a very short time. However, if one checks this out using population genetic models, one finds no evidence for it. And then there is the question of how large an impact a single major gene can have on a character as complex as language articulation and processing.

Neanderthals and *Homo sapiens* lived next to each other for tens of thousands of years. What led to the breakdown of this cohabitation?

Grupe: The Neanderthals have been habitually underestimated. They were certainly not as primitive as they have often been painted. Their stone tools were of very high quality, for instance. They had a concept of transcendence, because they were the first to bury their dead. They successfully coped with ice ages and with warm periods. That *H. sapiens* was the first to decorate caves is something we tend to overemphasize, but there is no evidence to suggest that the Neanderthals were inferior to us. They ranged over a region stretching from Western Europe to the Near East, where they probably encountered *H. sapiens*. The two species probably lived side by side for tens of thousands of years. Whether or not the fossil record includes examples of hybridization between Neanderthals and *H. sapiens* is still being debated. Genetically speaking, it should certainly have been possible.

So why did the Neanderthals subsequently disappear?

Grupe: If anatomically modern humans had a slightly higher birthrate or a slightly lower mortality rate, modeling studies show that they could have outcompeted the Neanderthals in the restricted area which they shared within about 1,000 years. It didn't have to be war to the death. I imagine that the encounter was essentially peaceful.

About 11,000 years ago, the first agricultural societies appeared. Hunter-gatherers became farmers and began to plant cereals and other crops, and they domesticated livestock. These developments radically altered living conditions, and would eventually lead to the virtually complete replacement of the hunter-gatherer's way of life. What led to this momentous transition?

Grupe: Settled societies first emerged in the Middle Stone Age, in coastal locations with easy access to the sea, where the ecological conditions made permanent settlement possible. The novel subsistence strategies did indeed emerge 11,000 years ago. Archaeologists have shown that agriculture was invented independently five times on different continents. The Levant and Mesopotamia, the area between the Euphrates and the Tigris, was first to get off the ground.

Why there in particular?

Grupe: There was climatic optimum with

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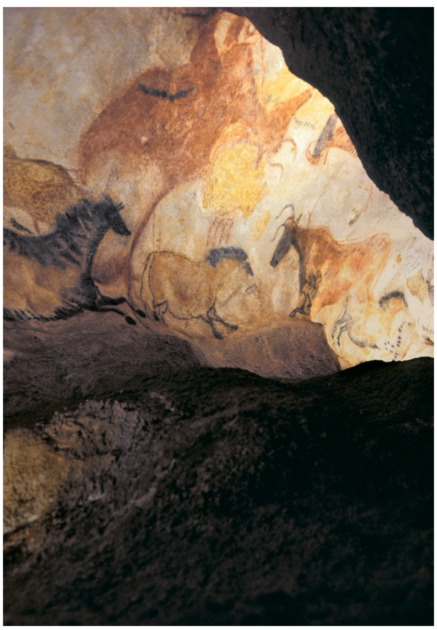
more rainfall than before. As a result, the migratory routes followed by the gazelle, the hunter-gatherers' main prey in the area, changed, and this was a world in which the intimate relationship between humans and the animals he hunted played a major role. Finds made at Göbekli Tepe in southeast Anatolia illuminate this relationship. Excavations undertaken since the 1990s have revealed the remains



An early sign of the superiority of *Homo sapiens*? In Gisela Grupe's view, the significance of cave paintings like those in Lascaux in France has been "overemphasized" in comparisons with the cultural accomplishments of Neanderthals.
Source: picture alliance/Bildagentur-online

of large-scale cult sites, over 10,000 years old, built by hunter-gatherers. This was truly monumental architecture, temples with pillars consisting of stacked 15-ton blocks – which pre-date the invention of the wheel. These temples are richly decorated with reliefs, which depict wild animals in an incredibly realistic fashion. Favourable climatic conditions and the belief in a spiritual world may have provided the impetus for the domestication of animals, especially because the only species of sheep and goat that are amenable to domestication, the moufflon and the bezoar goat, were endemic to the region. Large stands of wild wheat were also a feature of the landscape. And a single mutation was sufficient to ensure that the ripe grain remained attached to the ear – and could be harvested using sickles made of flint.

The change in the composition of the diet also left its mark in our genomes. Dependence on cereal crops meant that the human diet became richer in carbohydrates, which favored amplification and diversification of the ancestral gene for the enzyme amylase, which breaks down starch into glucose. People also had to adapt genetically to the intake of cows' and goats' milk.

Grupe: In the beginning, only nursing infants could digest milk. The gene for lactase, the enzyme that breaks down the lactose in milk, is turned off soon after babies have been weaned. But the mutation that allows adults to continue producing the enzyme is now virtually ubiquitous in European and American populations.

How did lactose tolerance evolve?

Grupe: This issue is still being debated. The mutation was presumably already present at a low frequency. But only with the onset of animal domestication did this hitherto useless mutation confer an advantage. That's why I think the frequency of the mutant allele in the population soared very rapidly, which is what all modeling studies suggest. The real question is when it all happened. It is now possible to reconstruct our ancestors' diets with the help of stable-isotope analyses, and these tell us that agriculture arrived in Central Europe around 5500 BCE, but dairy farming only becomes prominent 2,000 years later.

Stephan: If a mutation is already present as a rare genetic variant in the population, then selective forces can increase its frequency to nearly 100% in a very short time, 100 generations or so. The frequency of the mutation for blue eyes, for example, increased in the Northern European population at a similarly rapid rate. But some researchers assume that these two examples involved not pre-existing alleles, but novel mutations that enabled people to adapt to changes in environmental conditions. The four mutations linked to lactose tolerance in different populations cluster in a tiny segment of DNA only 100 base-pairs long – which implies that this is a hypermutable region.

Humans have always been able to adapt – but they also remodeled their natural environment.

Stephan: Humans have been modifying the natural environment in more or less dramatic ways at least since the advent of agriculture and stock-raising – and in so doing have exposed themselves to new selection pressures. Improved nutrition meant larger populations and settlements increased in size. Even in the early phase of urbanization, as population densities increased hygiene became a problem, favoring the spread of infectious diseases. Eventually, with the birth of the modern world, we entered an era in which unprecedentedly complex forms of civilization emerged, bringing new problems with which we are all familiar – from the overexploitation of resources to the destruction of natural habitats to digital overload, from life in megacities to the stresses associated with the demands of constant social and communicative accessibility.

What does this mean for biological evolution? Where is evolution taking humanity?

Stephan: The human population has

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grown to over 8 billion, increasing by more than 1,000-fold in 1,000 years. And since the onset of the industrial revolution 150 years ago, the rate of growth has been rising ever more steeply. In terms of population genetics, this explosive growth represents a drastic departure from equilibrium. We cannot yet scientifically assess the effects of this demographic process. At all events, the success of modern medicine means that the impact of natural selection is now minimal. This in turn means that each human is now accumulating five or six deleterious mutations per generation. What impact will this have on the co-evolution between humans and microorganisms? Will the world's populations be able to withstand the onslaught of new plagues? These are questions that we can only speculate about. Furthermore, climate change promoted by human activities threatens to eliminate what remains of the natural environment. The distribution patterns of animals and plants are changing dramatically. In that sense, the more pertinent question might be: Where is humanity taking evolution?

Grupe: It is epistemologically impossible to predict what direction evolution may take. That can only be recognized in retrospect. We cannot simply decide that we are going to keep the show on the road for the next 300 million years. Looking at the issue dispassionately, one must admit that an awful lot of species on this globe are biologically more successful than we are. They were here long before us and they are still here.

Translation: Paul Hardy

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