New research reveals effects of the Agricultural Revolution on human evolution

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15 January 2016

Humans are "artificial apes," as one modern anthropologist put it, highlighting the role of technology in the development of human society. From the earliest beginnings of humanity, technological innovation and biological evolution have been dialectically linked in an intricate web of reciprocal determination.

Selective pressures triggered by the development of tools and other aspects of culture have prompted biological changes, not only in obvious features such as the hand and the brain, but in many other human physical characteristics. At the same time, biological changes, such as the elaboration of brain architecture (permitting increasingly sophisticated abstract thought) and increased manual dexterity (e.g., the fully opposable thumb and other changes in wrist and hand bones) have facilitated and promoted cultural innovation. Several recently published scientific articles elucidate this complex process.

The development of agriculture (the domestication of select plants and animals) was the most profound cultural innovation that humans have accomplished since the initial development of tools. Evidence of domestication begins to appear in the archeological record following the end of the last Ice Age (the end of the Pleistocene, roughly 10,000-12,000 years ago), though the process may have begun earlier, at least in some areas.

During the great majority of human existence, even if we only count the span of modern humans (dating back 200,000 years at most), people lived off naturally occurring resources, by hunting animals and gathering plant foods. This economic system is generally known as hunting and gathering or foraging. The independent development of agriculture more or less simultaneously (compared to the time frame of human existence) in a number of regions of the world, was a truly revolutionary change, and strongly suggests that some global process was at work. While much remains to be learned about the mechanisms that accomplished this change, the consequences were many and varied.

The most significant among these was the ability to produce a surplus of food beyond the immediate needs of daily subsistence. Some hunter-gatherer groups, such as those harvesting large annual fish runs on the northwest coast of North America, could amass and store food surpluses, but the quantities were limited by the natural abundance, timing, and geographic location of the resource, which could not be manipulated. By contrast, plant and animal husbandry, the care and controlled breeding of selected species, led to genetic changes that allowed greater yields and increased the geographic ranges across which the domesticated species could be grown, among other changes, thus greatly expanding the potential food resources available to humans.

These developments produced a revolution in human life. Most notably, the increase in abundance and reliability of food allowed human groups increased sedentism. Communities that had hitherto been relatively small in size and forced to make seasonal moves across the landscape to follow the shifting availability of naturally occurring resources could now stay in one place for long periods and grow in population size. In turn, this permitted the elaboration of the division of labor. Specialization further promoted technological innovation. And, while some limited social stratification existed among certain hunter-gatherers (like the native peoples of the northwest coast referenced above), the development of agriculture greatly amplified such tendencies and, ultimately, led to the formation of full-fledged class divisions.

These changes also had consequences for human biology. Alterations in diet leading to nutritional deficiencies, increases in tooth decay, and other problems; shifts in the patterns of labor; increased exposure to diseases (due to living in larger settlements); and the effects of living in new climates, among others, resulted in evolutionary changes, in reaction to, but also in some ways enhancing human's ability to live under the new conditions brought about by agriculture.

Several studies published over the past year highlight increases in the understanding of this complex process.

Research published in the *Proceedings of the National Academy of Sciences* (Timothy M. Ryan and Colin N. Shaw, "Gracility of the modern Homo sapiens skeleton is the result of decreased biomechanical loading," *PNAS* vol. 112 no. 2, 13 Jan 2015) examined the relative massiveness (gracility vs. robusticity) of the human skeleton before and after the advent of agriculture and contrasted these with a variety of living primates. The study compared bone density in the hip joints of specimens from 31 extant primate taxa with human remains from four separate archaeological populations including both hunter-gatherers and sedentary agriculturalists. All the human populations whose remains were examined were from Native American sites in eastern North America.

The study showed that hunter-gatherers, living about 7,000 years ago, had bone strength (the ability to withstand breakage) proportionally similar to that seen in the sample of modern primates. By contrast, agriculturalists, living 6,000 years later, had significantly lighter and weaker bones, more susceptible to breakage. Their bone mass was 20 percent less than that of their predecessors. These findings suggest that the decreased skeletal robusticity in recent humans is not the result of bipedality (walking on two limbs rather than four, which occurred millions of years ago), but rather has to do with the development of agriculture.

The researchers reviewed data to examine whether changes in diet, like reduced calcium intake, between hunter-gatherers and agriculturalists may be the primary reason for differences in bone density. They conclude, however, that it is principally changes in the pattern of physical activity, from highly mobile foragers to relatively sedentary agriculturalists that explain these differences.

These findings do not imply that farmers work less than foragers. Indeed, anthropological research has shown that at least some foragers have more free time than agriculturalists. One distinction may be the necessity for frequent movement from one settlement to another by the former. This is supported by the results of another study, published in the same issue of *PNAS* (Habiba Chirchir, et al., "Recent origin of low trabecular bone density in modern humans," *PNAS* vol. 112 no. 2, 13 Jan 2015), which demonstrates that changes in bone density were more marked in the lower limbs than in the upper. It reviewed hominin fossils from a number of extinct species, stretching back to *Australopithecus africanus* , demonstrating that high bone densities were maintained throughout the span of human evolution until the development of agriculture. This raises the question of whether changes in anatomy aside from bone density may be identifiable as resulting from activities characteristic of an agricultural existence.

The results are important in understanding the evolutionary context of such diseases as osteoporosis and geriatric bone loss in contemporary populations.

Another study, this one published in the journal *Nature* (Iain Mathieson et al., "Genome-wide patterns of selection in 230 ancient Eurasians," *Nature*, 16152, 23 November 2015), uses ancient DNA to trace the arrival of the first farmers from the Near East into Europe and examine a number of genetic changes experienced by the immigrants. The adaptations include changes in height, digestion, the immune system, and skin color.

DNA recovered from samples of ancient human bone provides a new source of data, supplementing archaeological artifacts, anatomical studies of human skeletons, and studies of DNA from contemporary human populations, to examine the introduction of agriculture into Europe. In particular, ancient DNA provides a more direct view of the evolutionary changes that humans underwent as they and their recently developed agricultural technology adapted to a new environment.

Modern humans moved into Europe from the Near East sometime between 40,000 and 50,000 years ago, absorbing and/or displacing the existing Neanderthal inhabitants. Both populations had hunting and gathering economies. Then, about 8,500 years ago, new immigrants, also from the Near East, began spreading into Europe. This time, however, they brought with them a revolutionary new economic system—agriculture. Another wave of agriculturalists moved into Europe from the Russian steppes, about 2,300 years ago.

The study reported in *Nature* compared ancient DNA from Europe, Turkey, and Russia with that from modern populations.

Foragers, who rely on naturally occurring foods, tend to have a varied diet in order to cover their nutritional needs. Agriculturalists, on the other hand, focus on a relatively narrow range of plant and/or animal species, perhaps supplemented by some wild food resources. This more limited diet may not meet all dietary requirements or may predominantly rely on foods that, while conducive to domestication, may not be easily digested. Dairy products and wheat are examples.

The consumption of milk and milk products is not natural for adult mammals. The capacity to digest lactose, a milk sugar, exists in infant mammals, but is usually lost once they are weaned. The domestication of a number of larger mammals, including sheep, goats, and cattle, presented the possibility of using their milk as a food source, converting grass, an abundant resource, but indigestible to humans, into a new food source. However, since hunter-gatherers do not typically consume milk, the widespread lactose-intolerance in adult humans was a major problem for early farmers who sought to employ this food source.

One of the results of the *Nature* study indicates that a gene that allows lactose digestion to continue into adulthood appears to have taken thousands of years to become widespread in European populations, despite its apparent selective advantage, only beginning to appear about 4,000 years ago. This raises the question of whether technological adaptations, such as the production of aged cheese, which has less lactose, may have allowed for the use of milk products in earlier times.

Another gene was identified that enhances the ability to absorb an important amino acid, ergothioneine, which exists in low amounts in wheat and other domesticated grains. The spread of such a gene would represent a distinct advantage for diets that focused on grains as a food source. However, the effects of genes are often complex, and sometimes have unexpected consequences. This same gene appears to raise the risk of digestive disorders, such as irritable bowel syndrome. Evolutionary adaptations often represent a dynamic balance between positive and negative effects.

The researchers also found evidence regarding an evolutionary change in skin color. The predominance of lightly colored skin among Europeans appears to be a relatively recent phenomenon, possibly related to the need to produce more Vitamin D, which can occur in a reaction caused by sunlight absorbed in the skin. Lighter colored skin is thought to facilitate this process.

The study concludes that modern Europeans have significant genetic differences with early Neolithic populations of the region, despite having a largely common ancestry. The authors propose that these differences reflect evolutionary adaptations to the adoption of an agricultural lifestyle in a new environment as well as successive waves of immigration.

These findings are valuable in that they reinforce our understanding that human physical evolution is a complex and dynamic process of dialectical interaction with the natural and cultural environment. In a very real sense, the development of agriculture involved not only the domestication of a range of plants and animals by humans, but, as part of that process, the transformation of the humans themselves.