

A Short Guide to the Evolution of Human Intelligence: A Timeline for the Evolution of *Homo Sapiens* Over the Last Sixty Million Years

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ABSTRACT

*This teaching aid reviews the major evolutionary landmarks that over the last sixty million years marked the development of intelligence in *Homo sapiens*. The discussion begins with social primates and charts the adaptations that ultimately led to the emergence of modern humans including the growth of the brain, increased manual dexterity, and evolution of language. Discussion includes consideration of the following gene mutations: RNF213 GENE, HAR1 GENE, ARHGAP11B GENE, SLC2A1 GENE, SLC2A4 GENE, HACNS1 GENE, MYH16 GENE, SRGAP2 GENE, FOXP2 GENE, AMY1 GENE*

KEYWORDS

ARCHAEOLOGY, BIOLOGICAL ANTHROPOLOGY, HUMAN EVOLUTION, EVOLUTIONARY BIOLOGY, LANGUAGE, GENETICS, HOMO SAPIEN, HOMO HABILIS, AUSTRALOPITHECINES, PRIMATES, CHIMPANZEE, GORILLA, GELADA, MOYAMOYA DISEASE, CAROTID ARTERY, HOMININ, WONDERWERK CAVE, SOUTH AFRICA, STARCH DIET, MEAT DIET, RNF213 GENE MUTATIONS, HAR1 GENE, ARHGAP11B GENE, SLC2A1 GENE, SLC2A4 GENE, HACNS1 GENE, MYH16 GENE, SRGAP2 GENE, FOXP2 GENE, AMY1 GENE

INTRODUCTION

The success of the human species, marked not least by its development and application of technology, results from millions of years of evolution. *Homo sapiens* are notable for their large brains, in relation to overall body size, which facilitate the manipulation of abstract concepts and communication of complex ideas. These evolutionary advantages did not come without cost, and on the 'down-side' large brains make pregnancy a difficult and sometimes dangerous process. Other less obvious beneficial adaptations are the loss of most body hair and jaw muscle.

This paper presents an overview of the current state of knowledge, and is primarily for students taking introductory papers. It is meant to supplement text-books, teaching and reading lists, and focuses on named genetic mutations that can be shown to have had an adaptive effect on human intelligence. A 'Further Reading' section is included at the end of the review.

SOCIAL PRIMATES

The name given to the group that includes monkeys and humans is the Primates. They first emerged following the extinction of the dinosaurs. A feature of the primates, that dates to between sixty and thirty million years ago, is that many of their members live in highly social groups (FIGURE 1). Group living requires that individuals develop an awareness of those with whom they live. It means being sensitive to friendships and rivalries, not just between oneself and the other group members, but also interactions between third parties. Processing this web of information and remembering where each group member stands within the group hierarchy may well have driven the steady evolution of increased brainpower.



FIGURE 1. A social group of Gelada Primates.

THE BRAIN OF A COMMON ANCESTOR

The common ancestor of Humans, chimpanzees and gorillas is an unknown extinct ape. In this ancestor between fifteen and ten million years ago, a gene called RNF213 began evolving rapidly. This may have boosted the flow of blood to the brain by widening the carotid artery (FIGURE 2). In humans, RNF213 mutations cause Moyamoya disease, in which the artery is too narrow.

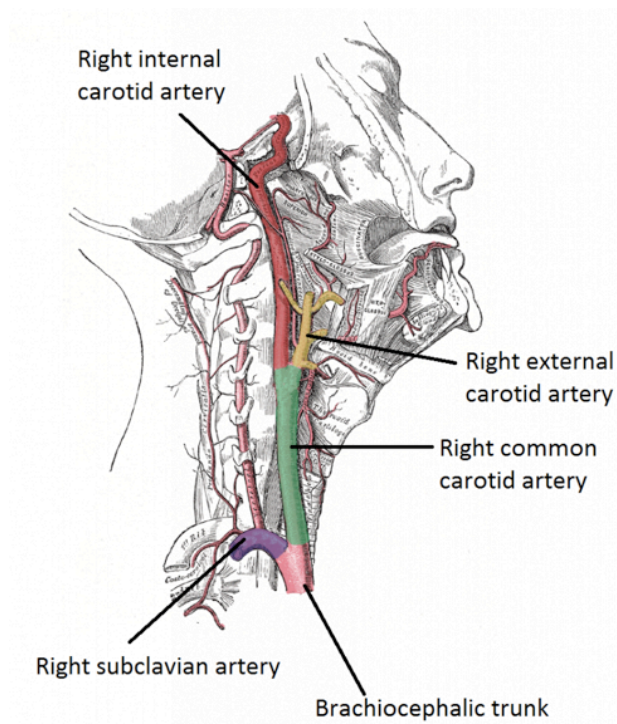


FIGURE 2. Anatomy of the carotid artery.

THE SPLIT FROM APES

Our ancestors split from their chimp-like relatives between thirteen and seven million years ago (FIGURE 3). At first, externally they would have looked similar, but within their cells, changes were taking place. Following the split, both the ASPM and ARHGAP11B genes, and a region called HAR1 began to change. It is not completely clear what impact the changes had, but the HAR1 region and ARHGAP11B are involved in the growth of the cerebral cortex. This suggests that the gene mutations were linked to cognitive changes.



FIGURE 3. Human and Gorilla.

BRAIN POWER

After the human lineage split from that of chimpanzees, which occurred within the last seven million years, two genes mutated: SLC2A1 and SLC2A4. Both of these genes build proteins that transport glucose in and out of cells. The tweaks made by the genetic changes may have had the effect of diverting glucose away from muscles and into the early hominins' brains. In the brain the glucose would provided more energy boosting the brains, and allowing them to increase in size (FIGURE 4).

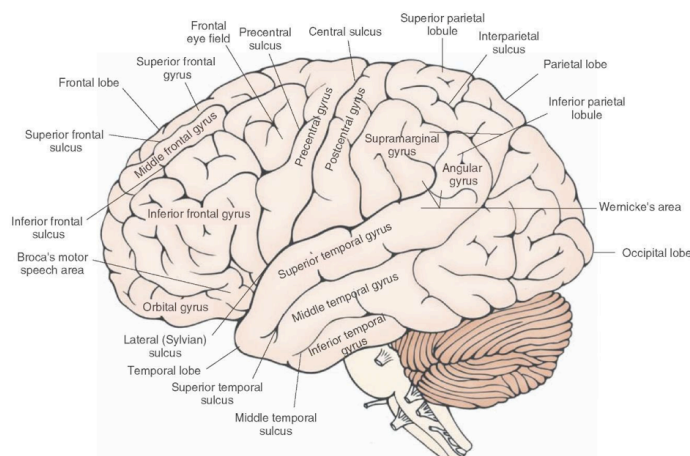


FIGURE 4. Anatomy of brain.

MANUAL DEXTERITY

The hands of *Homo sapiens* are unusually dextrous compared to other primates (FIGURE 5). This dexterity allowed them to develop early stone tool technologies and later writing. It appears from genetic studies that this adaptation is at least in part due to mutations in an area of DNA called HACNS1. During the last seven million years, since humans diverged from chimpanzees, this area of DNA has evolved rapidly. Our current state of knowledge leaves it unclear as to the precise function(s) of HACNS1, but it is active in the arms and hands as they develop, which suggests that it is linked to manual dexterity in *Homo sapiens*.

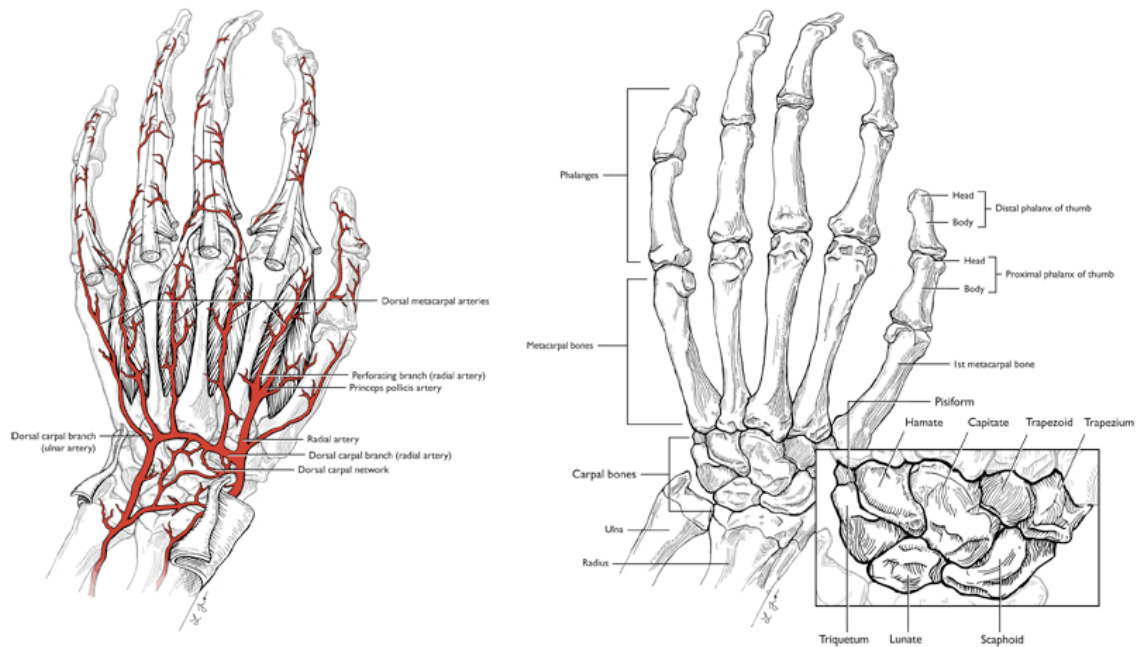


FIGURE 5. Anatomy of the human hand revealing its dexterity.

SLACK JAWED

Compared to other apes humans can't bite very hard, because they have weak jaw muscles (FIGURE 6). This is down to a mutation in the MYH16 gene, which controls the production of muscle, which happened between 5.3 and 2.4 million years ago. The smaller jaws could have freed up space for the brain to grow.

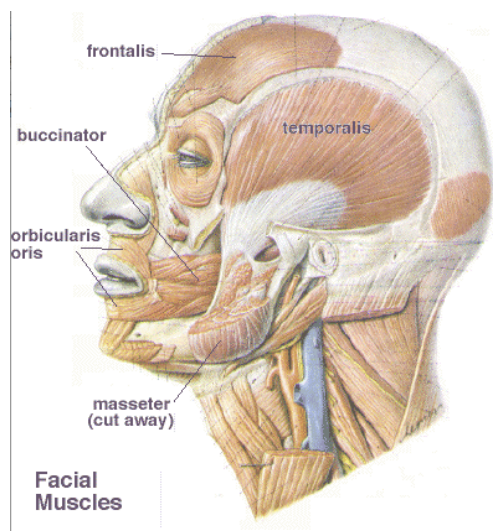


FIGURE 6. Muscles of the human jaw.

MEAT FEAST

Homo sapiens' oldest ape-like ancestors mostly ate fruit, but the later species of *Australopithecus* diversified their diet, a process that lasted from 3.5 to 1.8 million years ago (FIGURE 7) As well as eating a wider range of plants, such as grasses, they also ate a lot more meat. Archaeological evidence shows that they even used stone tools to butcher meat. Meat is more calorific than fruit for the same weight, and requires less chewing to digest than vegetables and grasses. The additional calories provided by meat allowed human ancestors to increase the size of their brain, which consumes large amounts of energy, as well as reducing the size of their jaw muscles.



FIGURE 7. The development of meat eating.

THE HAIRLESS APE

Between three and four million years ago human ancestors lost almost all their body hair (FIGURE 8). It is by no means clear why this occurred, but the development can be dated by the appearance of pubic lice. The lice evolved three to four million years ago, and since they could only infest our ancestors once their other body hair was gone we can be sure that almost all body hair had been shed by this time. Exposed to the Sun, the skin darkened, and thus all our ancestors were black, until comparatively recently when some modern humans left the tropics, and adapted to more northerly latitudes by losing skin pigmentation.



FIGURE 8. Humans: the hairless ape.

GENETIC INTELLIGENCE

Of all the genetic changes that made humans what they are, it is those that are linked to intelligence that are of most significance. Research shows that a gene called SRGAP2 was duplicated no less than three times. As a consequence, the ancestors of *Homo sapiens* had several copies, some of which appear to have evolved freely. One of the mutated copies turned out to be better than the original as it caused brain cells to extrude more spines, allowing them to form more synaptic connections, and thus increase cognitive ability (FIGURE 9).

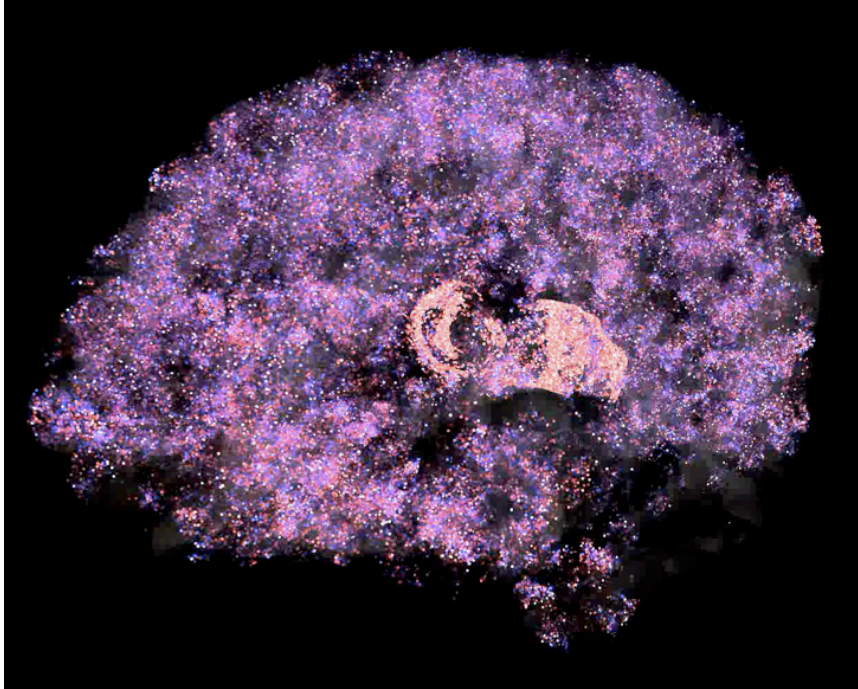


FIGURE 9. Brain synapses firing.

TECHNOLOGICAL THINKING

Modern humans belong to the 'genus' (group) of animals known as *Homo*. The oldest known *Homo* fossil, found in Ethiopia, is 2.8 million years old (FIGURE 10). The first species was probably *Homo habilis*, although this has been disputed, and new fossil discoveries are continually made. Compared to their ancestors, these new hominins had much larger brains.



FIGURE 10. *Homo Habilis*, reconstruction and fossil skull.

BIG HEADS

For *Homo sapiens*, childbirth is difficult and dangerous. Unlike other primates, human mothers almost always need help when giving birth. This is because adaptations to walking on two legs have included a narrowing of the pelvic canal, leaving less space for the baby to pass through during birth (FIGURE 11). Furthermore, the increase in brain size, discussed above, has led to an increase in the size of the head in modern humans. In order to partially compensate for the increased difficulty of birth, human babies are born whilst still small and helpless, and so need more and longer nursing care compared to other primates.

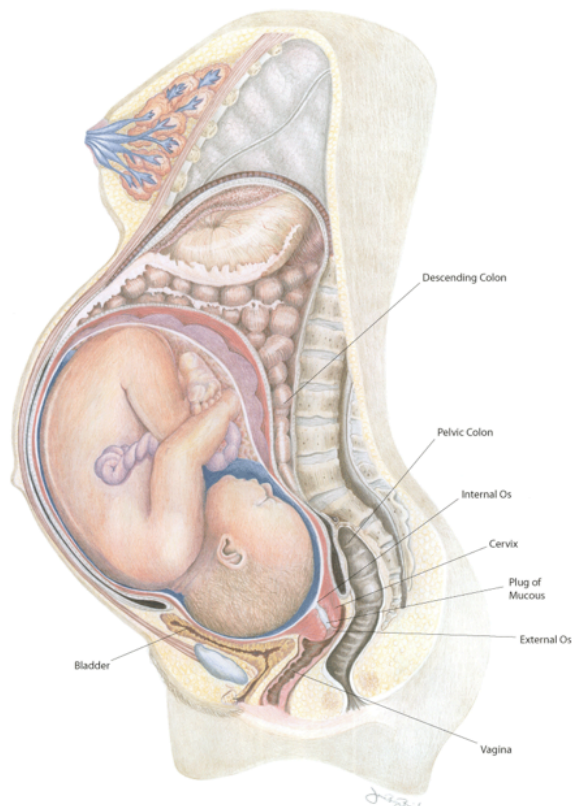


Figure 11. Anatomy of pregnant female *Homo sapiens*. The large head of the baby has to pass through the narrow birth canal, causing potential danger to both mother and infant.

FIRE STARTER

Something else that separates *Homo* from other primates and from its closest cousins is the ability to control fire (FIGURE 12). It is not known exactly when human ancestors first learned to control fire. The oldest direct evidence comes from Wonderwerk Cave in South Africa, which contains ashes and burned bones from one million years ago, but there is evidence hominins were processing, and possibly cooking, food even earlier.



FIGURE 12. A key developmental step, the ability to control fire.

TALK-THE-TALK

Unlike all other great apes, humans do not have air sacs on their vocal tracts. In the great apes these sacs allow them to make loud bellows. However the air sacs also make it impossible to produce different vowel sounds. It is only because human ancestors lost these sacs that modern humans are able to talk. Analysis suggests that the air sacs were lost before humans diverged from their Neanderthal cousins, suggesting the Neanderthals could also speak (FIGURE 13).



FIGURE 13. The data suggests that Neanderthals, like modern humans, were able to speak.

GRAMMAR AND PRONUNCIATION

A few people have mutations in a gene called FOXP2. As a result they struggle to grasp grammar and pronounce words. That suggests FOXP2 is crucial for learning and using language. The modern FOXP2 evolved in the common ancestor of humans and Neanderthals, about half a million years ago, as Neanderthal FOXP2 looks just like ours (FIGURE 14).

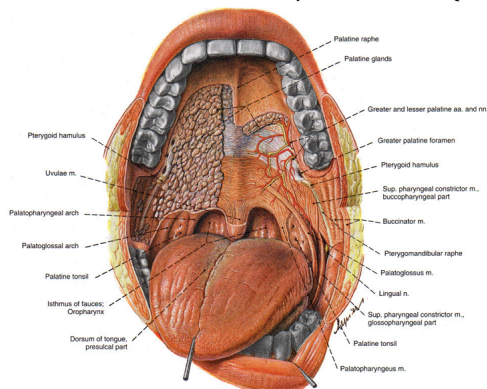


FIGURE 14. Both Humans and Neanderthals could talk.

STARCHY FOODS

Saliva contains the enzyme amylase, which digests starch (FIGURE 15). This enzyme is made by the AMY1 gene. Studies have shown that modern humans, whose ancestors were farmers, have more copies of the AMY1 gene than people whose ancestors continued with a hunter-gatherer-fisher way of life. The ability to digest starch is essential to an urban way of life, and the increase in frequency of AMY1 may have helped start farming, settled villages and modern societies, all of which have occurred since the end of the last ice age only ten thousand years ago.



FIGURE 15. One of the most plentiful supplies of starch in the modern diet is wheat.

DISCUSSION

The foregoing has provided a brief review of the current state of knowledge concerning the evolution of intelligence in modern humans, dealing in particular with named genetic mutations. Further information about these mutations can be found by following-up the references in the 'Further Reading' section below.

FURTHER READING: GENE MUTATIONS

AMY 1: <http://www.ncbi.nlm.nih.gov/gene/276>
ARHGAP11B: <http://www.ncbi.nlm.nih.gov/gene/89839>
FOXP2: <http://www.ncbi.nlm.nih.gov/gene/93986>
HACNS1: <http://mbe.oxfordjournals.org/content/28/11/3005.full>
HAR1: <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2441984/>
MYH16: <http://www.ncbi.nlm.nih.gov/gene/84176>
RNF213: <http://www.ncbi.nlm.nih.gov/gene/57674>
SLC2A1: <http://www.ncbi.nlm.nih.gov/gene/6513>
SLC2A4: <http://www.ncbi.nlm.nih.gov/gene/6517>
SRGAP2: <http://www.ncbi.nlm.nih.gov/gene/23380>