ALPHA 138

Human evolution

Dr Anna Meyer

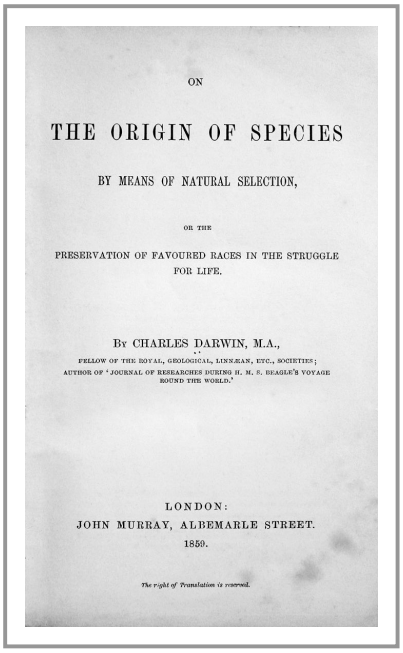
the ROYAL SOCIETY of NEW ZEALAND
TE APĀRANGI

Introduction
How did our species come to be the way it is today? In this *Alpha*, we take a look at the scientific topic of human evolution. First we journey through some of the stages of our past, looking at the human family tree, who some of our common ancestors were and how modern humans came about. Then we focus on some specific questions from our past, including what our relationship is with a well-known prehistoric race of people called Neanderthals, the origins of Polynesians and our relationship with our closest living relatives, chimpanzees.

What is evolution?
The word 'evolution' simply means that populations of living things keep changing over time. Because of evolution, the variety and type of plants, animals and bacteria that we see now on Earth are not exactly the same as they have been in the past. Like all other species on Earth, humans are part of this continuing process – we evolve and change over time.

How evolution works: Charles Darwin and natural selection
The idea that humans evolve has been around for a long time, but before the mid-1800s it was not widely accepted. At this time very few human ancestor fossils had been found, and there were no really good theories to explain how evolution works. This changed dramatically when the English scientist Charles Darwin published his now famous theory of natural selection in 1859. This is still what scientists use today to explain how evolution works – including human evolution.

Darwin's theory of natural selection says that lots of offspring are born in each generation, and each is very slightly different. Because of competition and limited resources, many more are born than are able to survive to produce their own offspring. On average, only the 'fittest' in each generation - those that can survive and reproduce in the environment they are in - pass their genes to the next generation. Through this process of natural selection, gradually over many generations, species evolve to suit their environment. As the environment continues to change, natural selection continues to occur.


ON

THE ORIGIN OF SPECIES

BY MEANS OF NATURAL SELECTION,

OR THE

PRESERVATION OF FAVOURED RACES IN THE STRUGGLE FOR LIFE.

By CHARLES DARWIN, M.A.,

FELLOW OF THE ROYAL, GEOLOGICAL, LINNEAN, ETC., SOCIETIES; AUTHOR OF 'JOURNAL OF RESEARCHES DURING H. M. S. BEAGLE'S VOYAGE ROUND THE WORLD.'

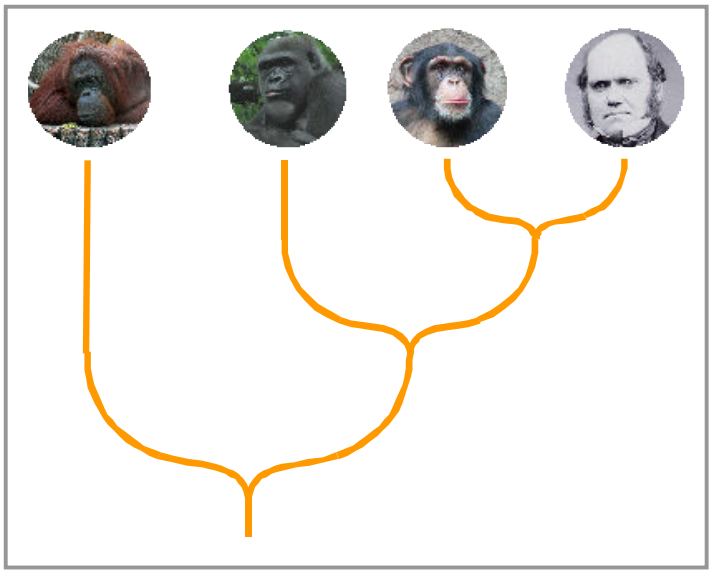
LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1859.

The right of Translation is reserved.

Natural selection means that populations can change from one form to another over time. However, as populations evolve they can also eventually split into two or more different species, which are then said to have had a 'common ancestor'. These new species can eventually split again, into more new species and so on, until eventually an entire 'evolutionary tree' of species forms. On the way, some species become extinct. These processes are how all species on Earth today have evolved, including humans.

After Darwin's theory was published, research into our origins became a very popular topic. After 150 years of work, we now have a good idea of the stages humans have been through in their evolution over the past several million years, but these ideas are constantly being updated as new evidence appears.

Human ancestry



A popular misconception is that humans are descended 'from' apes, but this is misleading - we simply share a common ancestor with them. Of the three living varieties of large apes (orangutans, gorillas and chimpanzees), humans are most closely related to chimps, which means we shared a common ancestor with them more recently. Interestingly, because chimps and gorillas occur naturally only in Africa, this indicates that the human lineage would also have to have started in Africa. Researchers have worked out that the common ancestor of humans and chimps was a species that lived about 5-7 million years ago. By natural selection, that ancestor species split into at least two new populations – one that led to humans, and one to chimpanzees. One lived in open savannah, which led to humans, the other in more forested land, which led to chimpanzees. Because of this shared evolutionary history, humans and chimpanzees share an interesting relationship today – something that we talk about in more detail a few pages on.

The human family tree

Once the split between the human and chimpanzee lineages happened, the line leading to humans continued to evolve and divide further, and a whole family tree of human relatives began to appear. Species on this tree are known as 'hominids', and many fossils have been found that lie somewhere on it. Some are likely to be our direct ancestors, and some are 'side branches' – species which are closely related, but did not lead directly to us. There is often much scientific debate as to whether a fossil species is a direct ancestor or a side branch on the human family tree. The important thing to remember is that humans are the only living descendants of this once bushy family tree - we are the only surviving hominid.

African ancestors

All the earliest fossils on the hominid family tree are found only in Africa. A variety of early hominid fossils have been found, which can be divided into several different species. Below are just some of the these.

Ardipithecus ramid

This species is widely considered to be the oldest hominid currently known. It lived about 4.4 million years ago – soon after the human and chimp lineages split. Fossils of this species have been found only in Ethiopia. It had some ape-like features and some hominid-like features, and probably looked quite a lot like the common ancestor of humans and chimps. It may have walked upright, but this is not known for certain.

Australopithecus afarensis

This species is known to have lived in Ethiopia, Kenya and Tanzania about 3-4 million years ago. Many examples have been found, the best of which is an almost complete skeleton nicknamed 'Lucy'. This species lived for a very long time – about a million years. It had some ape-like features, such as a forward protruding face, and a small brain case, about the size of a modern chimpanzee. It had a low forehead, a large brow ridge, and was about one third the size of a modern human. This species did, however, have one very human trait - it walked upright.

Australopithecus africanus

This species lived from 3.3 to 2.5 million years ago, and fossils of it have been found in South Africa. This was one of the first hominids to be discovered, in 1925. *A. africanus* had large rear teeth and large chewing muscles, so probably ate tough, fibrous food. It had a very similar body and brain size to *A. afarensis*, and almost certainly also walked upright. It is not clear if this species was a direct ancestor of humans, or a side branch that eventually became extinct.

Homo habilis

The earliest known member of our own genus, *Homo habilis* lived about 2.5 to 1.6 million years ago, also in Africa. This is also the time that the first stone tools appeared - hence the name, *Homo habilis*, or 'Handy Human'. This species had a 50 percent bigger brain in relation its body size compared to earlier hominids, and had opposable thumbs, meaning it could do fiddly tasks with its hands. It may also have been capable of basic speech.

The first big O.E.

All the hominids mentioned so far lived only in Africa. With the evolution of a new species about 1.5 million years ago, this changed forever. *Homo erectus,* or 'Upright Human', evolved in Africa, like all hominids before it. However, something dramatically different happened – *H. erectus* began to travel. For the first time, a hominid species spread throughout much of the world, including Asia, the Middle East, India and Europe (but not Australia or the Americas).

Homo erectus fossils from different regions show slightly different skeletal features. These are much like the small variations that can be seen in people all over the world today, but much more pronounced. These differences make many researchers consider that the groups of *H. erectus* were so different that they were each separate species, unlike modern-day humans, who are all members of the one species, *Homo sapiens.*

The origin of modern humans
So where are all the *Homo erectus* descendants and all the other hominids now? Half a million years or so ago there were many varieties, spread throughout Africa and much of the world, but they are no longer here. Modern humans, *Homo sapiens,* are the only surviving species left on what was once a bushy family tree. When and where did modern humans evolve? And what happened to all the other hominids?

Out of Africa
The most widely accepted theory on how modern humans evolved and what happened to the other hominids is known as the 'Out of Africa' theory. This suggests there were two 'out of Africa' events. Firstly *Homo erectus* left Africa and populated much of Earth. Modern humans (*Homo sapiens*) then evolved in Africa only, from just one descendant group of *Homo erectus* that existed there. Modern humans then spread throughout the rest of the world, replacing all the other descendants of *Homo erectus*.

How the proposed takeover might have happened is not entirely clear. However, it is possible that earlier humans might have directly conflicted with the other hominids. Alternatively, they might simply have out-competed them for food and resources – perhaps they were better organised, had better tools or a more developed language.

What is the evidence for this theory?
This has been the subject of a lot of scientific debate and research, at first using fossils, and now also DNA.

Fossils are very useful, but they do have their limits, and on the question of modern human origins they have led to more arguments than answers. Out of Africa supporters believe that the fossil record shows an abrupt difference between the various races of *Homo erectus* and modern humans, proving that it was not possible for *Homo erectus* to have evolved into modern humans in most regions of the world. The one exception to this, say the supporters of the theory, was in Africa, where they believe the *Homo erectus* fossils do show a smooth transition to modern humans, in agreement with their theory. However, not all researchers agree with this, and there has been a lot of debate.

More recently, a new method has been used to study our origins – the analysis of human DNA. This has provided some interesting answers to the question of when and where modern humans evolved, and who we are descended from. The way it works is this: DNA is passed on from ancestor to descendant, but over time mutations, or changes, tend to occur. The result is that the more closely related two living things are to each other, the more similar their DNA is likely to be. It follows that if two living things have very similar DNA, they must have shared a common ancestor quite recently.

Researchers have extracted DNA from tens of thousands of people from all around the world. By comparing the DNA, they have found that all humans, from anywhere in the world, have extremely similar DNA. This result, which seems very simple, means something very important - that humans are all very closely related, and are therefore likely to have had a very recent common ancestor, less than 200,000 years ago.

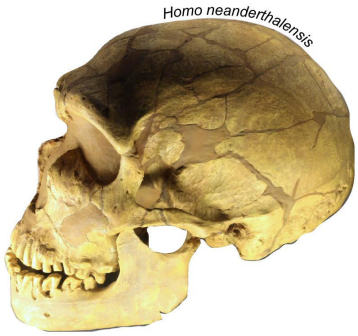
The DNA therefore strongly supports the 'Out of Africa' theory. *Homo sapiens*, it seems, are actually a very recent species on Earth. This is an interesting example of how science works – setting questions, and finding more and more evidence.

Humans and Neanderthals

As well as looking at how the human family tree evolved, and where modern humans came from, researchers are also interested in specific events that happened during our evolutionary past. One of these is the disappearance of the Neanderthals (*Homo neanderthalensis*), prehistoric people who lived in an area stretching right across Europe and Western Asia, including parts of the Middle East. Neanderthals evolved around 300,000 years ago as descendants of one of the races of *Homo erectus* that lived in this area. Around 30,000 years ago they disappeared. The subject of what happened to them, and how they are related to humans, has led to a lot of debate.

What Were Neanderthals Like?

Neanderthals are often portrayed as primitive, rude and disgusting, with huge muscles and very low intelligence. But were they really like this? It is true that they were extremely strong, and they had huge jaw muscles, with enormous bite strength. Neanderthals also had large faces, low foreheads and huge brow ridges. If you feel your own chin, you will find a bony piece poking out at the bottom of your jaw. Neanderthals did not have this, so their chins receded.



There is no way of knowing how Neanderthal thought processes worked, but their brains were slightly larger than ours. Neanderthals did make fairly simple tools, but did not make intricate ornaments or cave paintings. They did bury their dead, something no animal apart from humans is known to have done. It is not known how developed their language was.

Were Neanderthals human ancestors?

The first Neanderthal skeleton to be recognised was found in 1856 in a limestone quarry in Germany's Neander Valley. The relationship between humans and Neanderthals has been debated ever since. There are two basic options:

- they were the ancestors of modern-day humans in the part of the world that they lived

or

- they were a side branch on the human family tree.

A few years ago, researchers wondered if it might be possible to answer this question by extracting DNA from a Neanderthal bone, and comparing it to DNA from modern-day humans. If Neanderthals really were one of our ancestors, they would have passed their DNA on to their modern human descendants, and it should be quite similar to our DNA. On the other hand, if Neanderthals were not human ancestors, but only a more distant relative, Neanderthal DNA should be quite different to ours.

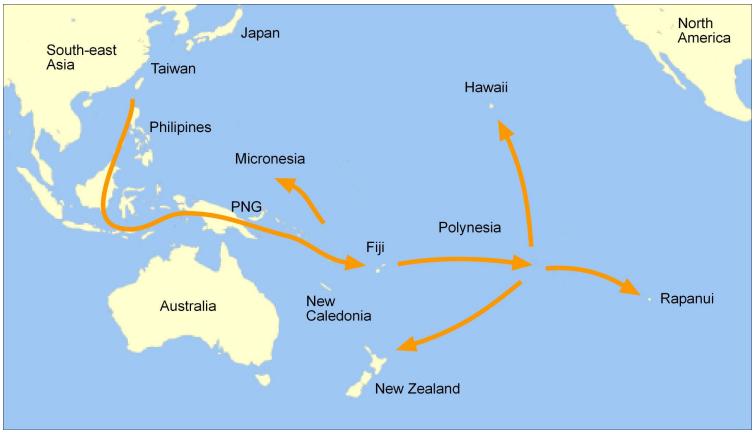
Eventually researchers managed to extract and analyse DNA from several Neanderthals. The results were strong – the DNA of humans and Neanderthals is quite different. This is true for two different types of Neanderthal DNA – mitochondrial and Y-chromosome. If Neanderthals truly were human ancestors, their DNA would have been much more similar to that of modern humans. Instead, the DNA provided the first clear evidence that Neanderthals could not possibly have been human ancestors. The mystery was solved at last - Neanderthals are simply an extinct species – but a very interesting one!

The origins of Polynesians
Soon after modern humans evolved up to 200,000 years ago, they moved out of Africa and colonised the rest of the world, including Australia by 50,000 years ago and the Americas by 11,000 years ago. The last area to be settled was the Pacific, and this amazing event is the focus of much research. In a relatively short time span, people navigated huge and often dangerous stretches of ocean, bringing settlers to some of the most remote corners of the world.

Where did Polynesians come from?
Scientists studying the origins of Polynesians have found that there is a close match between the DNA of Polynesians and the indigenous people of Taiwan. This match gives a clear picture that Polynesians must be at least partially descended from Taiwanese ancestors.

When did settlement of Polynesia begin?
Again, DNA has had a role in answering this question. In agreement with archaeological and other evidence, DNA indicates that Polynesian ancestors left Taiwan about 5000-6000 years ago, as part of a wave of human migration known as the Austronesian expansion. After leaving Taiwan the ancestors moved into the Pacific via regions of island east Asia, such as the Philippines.

Was settlement of Polynesia deliberate?
Oral histories, archaeological findings and modern simulations of ancient sailing methods support the belief that settlement was deliberate. DNA evidence also indicates that the colonisation of the Pacific was definitely not an accidental migration. DNA has been used to calculate the number of Polynesian females required to found the Maori population of New Zealand. Analysis indicates there were from 70 - 190 women in the first voyage to the islands. Hardly likely in a fishing vessel blown off-course!



Suggested routes of colonisation in the south Pacific

In what order did settlement happen?
Archaeology indicates that Polynesia was settled in the west to east direction. Central eastern Polynesia first, then Hawaii, Rapanui (Easter Island), and finally New Zealand. DNA from Polynesians gets more similar the further east they are. This pattern, known as ‘genetic bottlenecks’, suggests that the settlement of the Pacific occurred through a process known as ‘island hopping’, where people spread, one island at a time, in a general west to east direction. Maori are the least genetically diverse of all, which agrees with other evidence that New Zealand was the last part of the Pacific to be settled.

Just another ape?
Perhaps the most interesting question in human evolution is: what does it really mean to be human? Are we really just another species of ape? Was our evolution unique?

The closest living relatives of humans are chimpanzees, followed closely by gorillas. Chimps are actually more closely related to humans than they are to any other apes. The DNA of humans and chimps is around 98.8% the same.

Similarities and differences
Humans and apes are very similar in their physical makeup. We develop similarly as embryos and foetuses, and only show our differences in later stages of development. Like humans, apes use tools. Chimps use sticks to get at termites and rocks to break things. Apes can't talk like humans, but they do communicate with each other.

There are some interesting differences between us. One is the fact that humans make very complicated things, including tools and art. Although apes do use simple tools, they can't be trained to make more complicated ones. They have limited ability to think through tasks like this, and are also restricted by their hands – their thumbs don't move as freely as ours. Humans also have a more complex language ability than other apes. Some chimpanzees have been taught sign language, but they don't have the ability to speak as we do.

DNA comparisons
What is it in that tiny difference between our genes that causes the differences between us? Is there something really significant or special in there? Or are we really just another species of animal?

To answer this, researchers have very recently compared the genomes – the complete sets of DNA – of humans and chimpanzees. This comparison has meant that we can see exactly where and what the differences between us are. The comparison shows that, despite our apparent differences on the outside, human DNA is different to chimp DNA in only very subtle ways. We have almost exactly the same set of genes. Twenty nine percent of those genes are identical, and most of the others are only different by a tiny amount. We have only a few genes that chimps do not. This means that humans are, at a biological level, a totally natural, normal species. We just have some behaviour and abilities that are currently unique in the biological world.

The next task is to look at the differences that do exist and work out which ones actually make us look and behave differently from chimpanzees. It could be that some of the genes are turned on and off (expressed) differently in each species. Also, the genes that are different, although few, could have a big effect on things like speech and language.

Such similarity between us and chimpanzees - in our appearance, behaviour, and in our genes - would normally place us in the same genus. Currently, chimps are classified in the genus *Pan*, and humans have their own genus, *Homo*. Because of the similarities, some scientists feel that we should all be part of the same genus. Some also feel that chimps should be granted some of the legal rights that currently only humans have. What do you think?

Acknowledgments

Written by Dr Anna Meyer.
Reviewed by Professor David Penny, Massey University.
Edited and designed by Neville Gardner

Image credits
Page 2: Public Domain
Page 3: Neville Gardner
Page 4: adapted from photos by (from top) Durova, L. Borg, L. Borg, T. Roche (Wikimedia Commons)
Page 5 and 6: *Homo erectus* stone tools, Neville Gardner
Page 7: Polynesian islands: NASA
Page 8: Chimpanzee with stick, Dave Stegenga, copyright Honolulu Zoo www.honoluluzoo.org
Chimpanzee head, T. Lersch

References

Archaeology.info. *Ardipithecus ramidus.* Retrieved May 20, 2009 from http://www.archaeologyinfo.com/ardipithecusramidus.htm

McCall, B. (2004). *New light shed on chimp genome.* Retrieved May 20, 2009 from http://news.bbc.co.uk/2/hi/science/nature/3594937.stm

Meyer, A. (2005). *Hunting the double helix: How DNA is solving puzzles of the past.* Sydney: Allen & Unwin.

Orwant, R. (2005). *The chimpanzee genome is unveiled.* Retrieved May 20, 2009 from http://www.newscientist.com/article.ns?id=dn7930

Roach, J (2008) *Massive genetic study supports "Out of Africa" theory*. Retrieved 20 May 2009 from http://news.nationalgeographic.com/news/2008/02/080221-human-genetics.html

Smithsonian Institution. (n.d.). *Early human phylogeny.* Retrieved May 20, 2009 from http://www.mnh.si.edu/anthro/humanorigins/ha/a_tree.html

University of Auckland (2009). Pacific people spread from Taiwan, language evolution study shows. *ScienceDaily*. Retrieved May 20, 2009, from http://www.sciencedaily.com/releases/2009/01/090122141146.htm

WGBH Educational Foundation. (n.d.). *Origins of humankind.* Retrieved May 20, 2009 from http://www.pbs.org/wgbh/evolution/humans/humankind/b.html

Zimmer, C. (2001). *Evolution: the triumph of an idea.* New York: HarperCollins Publishers.

the ROYAL SOCIETY of NEW ZEALAND
TE APĀRANGI