Humans From Monkeys

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In June last year, I got the opportunity to participate in the annual Science Teachers' Training organized by Eklavya at Indore. 52 participants, young and old, attended the six-day training. Science teachers from schools run by the government, NGOs and other private schools were present. A few students and faculty working in the field of science education also participated in the training.

Trainees came from near and far. Several were locals, from Indore. Some came from nearby towns such as Dewas, Kannod and Mhow. Others came from places as far as Baran in Rajasthan and Allahabad and Kanpur in Uttar Pradesh. Many were new to the training and a few were old friends of Eklavya. All of us had the same goal - to better understand and teach science.

On the second day, as we wound up the session on evolution, we opened the floor to questions. A member of the audience asked a question which was addressed briefly at that time, but which I think deserves a more detailed response. The question was:

> "When children ask whether humans can evolve once again from monkeys, what answer do we give them?"

It's difficult to answer this question as the question is based on a misconception. So, first let's address this misconception: humans did not evolve from monkeys. Nor did we evolve from chimpanzees, our closest living primate relatives. However, humans and chimpanzees share a common ancestor, which was ape-like [apes are a group of primates in Africa and South-East Asia to which humans, chimpanzees, gorillas, gibbons, orangutans and bonobos belong; of these, humans and gibbons are found in India]. This common ancestor from whom we evolved existed some 5 to 8 million years ago. No fossil of this common ancestor has been found. The existence of this common ancestor has been deduced from both fossil and genetic studies of humans and other apes. These studies of have revealed common morphological traits and genes. The interpretations of these relationships between humans, apes and their ancestors are often subjective and lack clarity. There is a lot of debate surrounding the *exact* nature of relationships between them all. However, anthropologists and biologists are in agreement that humans and apes, both living and extinct are related, and share a common ancestor.

Humans from ape-like ancestors

So then, how did we come to be the *Homo sapiens* of today? Broadly, what happened was that from the common ancestor of humans and apes, several lineages evolved [Box 1]. Some of these survived, and some did not. What we know that is that one of the lineages from this common ancestor gave rise to chimpanzees and another to an early ancestor of humans, from whom we present day humans evolved.

Before we talk about the story of our evolution, it may be useful here to talk a little bit about what 'evolution' means so we understand it similarly.

Evolution in a population

Evolution refers to a change in the gene frequencies in a population over generations. A gene is a region of genetic material (such as DNA) that is inherited as a unit. These units contain instructions for the construction of proteins necessary for the various functions of our body. So, the frequency of a gene in a population refers to the proportion of individuals who possess this heritable unit of genetic material. Usually, when we speak of gene frequencies, we refer to the frequency of one gene, or a single trait.

Consider an isolated population of humans [this is a hypothetical example] thousands of years ago. Following a mutation/change in a gene that so far instructed the female body to produce one egg produced per menstrual cycle, two viable eggs are produced per cycle. This means that the female with this version of the gene, can now develop two embryos per pregnancy. In this manner a variant of a gene [an allele] for twins has been introduced into a population. Let us call this the gene for twins. Let us further assume that any female who has even one copy of this version of the gene will produce two children per pregnancy. Her children inherit this gene from her. Over several generations, many individuals in the population will possess this gene. If most females in the population have approximately the same number of pregnancies in their lifetimes, then simply because the ones with the gene for twins will have twice as many children as the ones without this gene, they will contribute more people to the next generation. Twins will further have twins, and this gene will in this manner spread in the population. Another assumption we are making here is that all other factors that influence survival and reproduction are equal.

So, following a mutation, from a very low frequency in the population, over several generations, the frequency of the gene for twins has increased. And the frequency of the gene for one child per pregnancy has decreased. Evolution has taken place in this population.

Box 1 – What is a lineage?

A lineage consists of sequence of species, each of which has evolved from its predecessor. For example, if we begin from a common ancestor, two lineages can form, each differing in certain character(s). Taking the character of brain volume (in relation to body mass), let us see one way in which two lineages can form over time. In Fig. 1 we see that 10 million years ago, brain volume/body mass is 3 cc/kg. By the time 9.5 million years ago, two groups have formed, with different brain volume/body mass numbers. These two lineages evolve separately. The zig-zag line of 'A' shows fluctuations in brain size with time (time increases in million years as you move from left to right along the horizontal axis), whereas brain size in 'B' seems to be increasing, rather steadily.

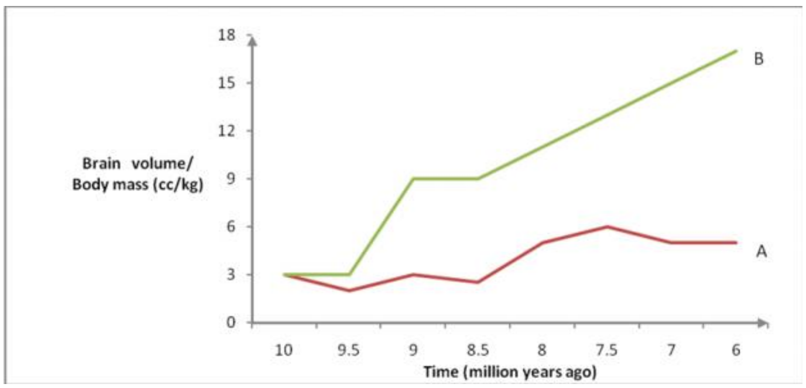


Fig. 1.

Note that in both lineages the brain volume has increased. However, other outcomes are possible.

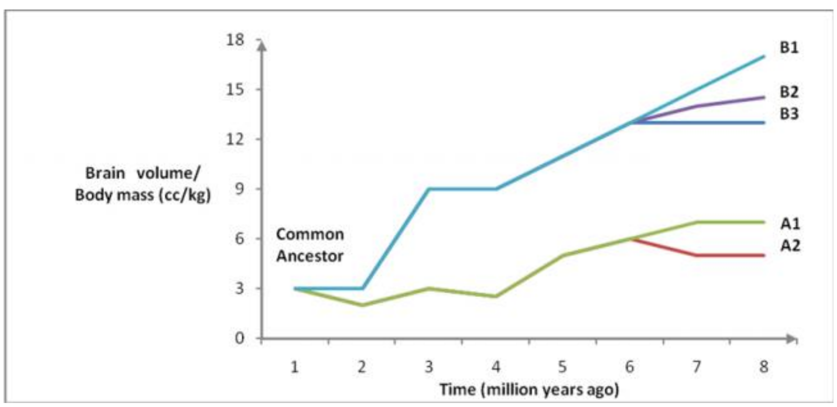


Fig.2. above shows an alternate scenario where in each lineage there is speciation to form multiple species. Some of these species will survive with time, perhaps even form lineages of their own. It is quite likely that some of the species will go extinct. It is also possible that the common ancestor of the two lineages survives as one of the species (for example B, B2, B3, rather than B1, B2, B3).

Evolution of new species

Changes in gene frequencies in a population can also lead to the formation of new species. Take the above example and imagine an alternative scenario. Following the introduction of the twin gene in a population the clan in which twins were being born are forced to leave their homes and migrate. This may happen for various reasons, such as due to a shortage of resources or due to harassment by others. What this means is that females with the gene for twins along with their relatives move to another location. Now, two groups exist in two different locations. There is no mating between the two groups. This means that there is no exchange of genes between the two groups – there is no gene flow between them.

Over many more generations, mutations, further changes in the genes occur in each of the populations. Of the heritable mutations, some persist in a population, some are expunged. Mutations occurring in one population are likely to be different from the other. Mutations that persist in one population are also likely to be different than the other, especially if the environments are very different. Genes that help individuals survive and reproduce more in each environment will be the ones that persist and passed on to the next generation. It is possible then that a time comes (many, many, many generations later) when the genetic makeup of the population in the new location becomes very different. So different that even if individuals from both populations are brought together, they are either unable to mate or the resulting offspring are not viable. These two populations now represent two species. In other words, the genes and their frequencies in the two populations are different enough to designate them as different species.

Other outcomes of evolution are possible. It's possible that only one of the population changes and evolves into a new species. Either one or both the species could become extinct. Evolution has still taken place, but we see only the surviving species.

In the remainder of the article, I mostly refer to evolution at this scale – the evolution of new species from ancestral species.

Humans from ape-like ancestors

To get back to our story about human evolution, what happened then – how did the ancestors of humans become *Homo sapiens*? Let us go back 5 million years ago and look at some of the events that can help us understand the nature of human evolution. Let me caution you, the following is one story, one model of human evolution based on fossils. As mentioned earlier, relationships deduced from fossils are often subjective. So, the same fossils can tell a different story, depending on whom you ask. There is broad agreement on many events, but a clear path of evolution of humans from their ancestors has been difficult to sketch. Anyway, let us barge ahead and look at some of the ancestral species and their relationships.

From fossil records, we know that a group of early humans whom we call the Australopithecines evolved in a lineage that split from the one that gave rise to chimpanzees. This took place around 5 million years ago, in Africa. Like other apes, individuals of this group were small. But unlike the others, they could walk upright – they were bipedal. We know this from several fossils that have been unearthed, dated and studied.

At this time, there were other changes taking place as well. The global climate became more seasonal, many forests were replaced with grasslands and savannas, and a greater variety of other species evolved.

From the Australopithecies, one of the lineages that arose was *Homo*. Fossils placed in this genus have been dated to a little over 2 million years ago. One of the earlier species in this lineage, *Homo habilis*, had larger brains than its ancestors. Fossils of another early human, *H.ergaster,* have also been dated to this period. It isn't entirely clear whether *H. ergaster* evolved from *H.habilis* or from a common *Homo* ancestor, but they did co-exist for a few hundred thousand years. Both *Homo* species made and used tools though they differed in the way they made them as well as in the implements they made. As far as we know, all this took place in Africa.

The first human ancestors to migrate out of Africa did so around this time. Fossils of another early human *H. erectus*, found both in Africa and across Asia are proof of this migration. By the time early humans further moved into the colder temperate regions of Asia and Europe, they had fire. In the following period, there were several waves of migrations within and out of Africa, into Asia and back into Africa.

Modern humans, *H. sapiens* evolved in Africa around 200,000 years ago and migrated out around 160,000 years ago. They had reached Australia via India and the East Indies by around 65,000 years ago. There is fossil evidence to show that at least two more species of humans also existed at this time – *H. neanderthalensis* in Europe and *H. floriensis* in Indonesia in Asia. After they migrated out of Africa, *H. sapiens* may not only have coexisted with *H. neanderthalensis* in Europe, but also with *H. erectus* in Asia.

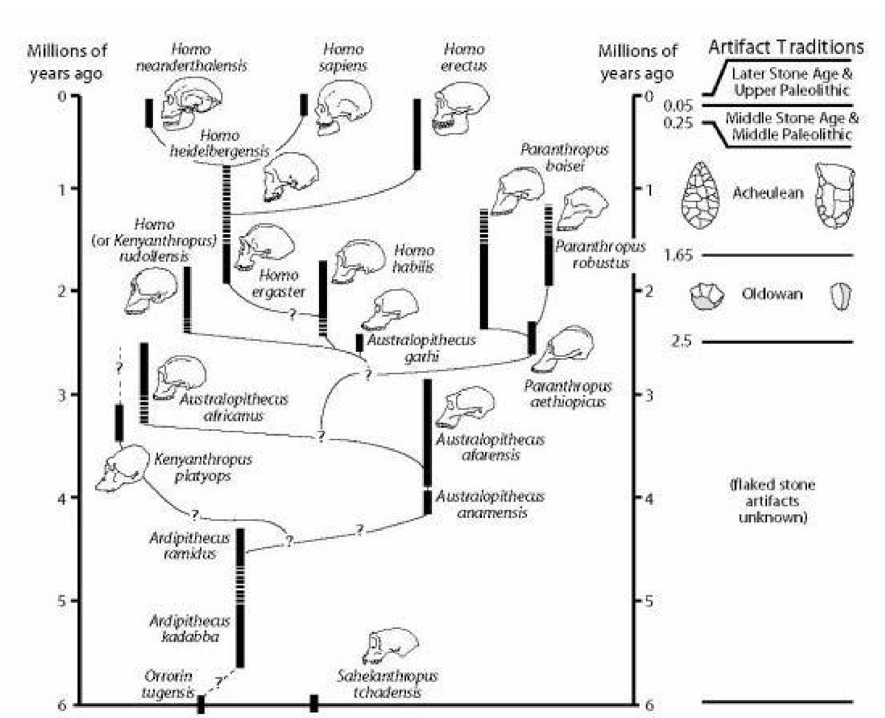
As the climate warmed, around 52,000 years ago, *H. sapiens* moved into Europe. 10,000 years later they moved into the arctic regions of Asia and Europe, and into North America around 25,000 years ago.

H. erectus went extinct around 70,000 years ago. *H. neanderthalensis* went extinct around 40, 000 years and *H. floriensis* around 10,000 years ago. *Homo sapiens* are currently the only surviving species of their genus.

This lengthy process of evolution of *H. sapiens* from apelike ancestors took place was driven by many factors. Changes in the environment - in climate, vegetation, in other species such as competitors, prey, parasites and predators - were probably some of the drivers of evolution. What this means is that as their environment and the species around them (even inside them) changed, individuals who survived and reproduced better in these new environments contributed more individuals to the next generation. In this manner, the genetic composition of populations of both human and other species changed slowly over time.

The relationships between humans and their ancestors (and apes) is probably best described as "bush" (Fig. 3) within which it is impossible to connect a full chronological series of species, leading to *Homo sapiens* that experts can agree upon.

Fig.3. An evolutionary bush of humans and their ancestors.



Can humans evolve once again from ape-like ancestors?

Now that we have some idea of how humans have evolved from their ancestors, we can address the question asked at the training session. Can humans then evolve from their (ape-like) ancestors once again?

This is a very unlikely event. While I cannot assign a probability to this event, we can safely assume it to be very, very low (naa key barabar). There are two reasons for this – one is that the ancestor from which modern humans evolved no longer exists. That ancestor is extinct, so the possibility of evolving from that ancestor is currently, nil.

However, were this ancestor still alive, the evolution of modern humans would still be a highly unlikely event. To begin with, in a population of the ancestral species, the same pairs of individuals would have to meet and mate as they did all those millions of years ago. In each pair, the females would have produced scores of eggs and the male millions of sperms. The same egg and sperm would have had to undergo fertilization to form the same embryos, for each pair, for each pregnancy, in each generation. Further, the series of environmental conditions over millions of years, both biotic and abiotic, as well as the random mutations in each generation will have to occur once again in exactly the same order to result in the outcome of the first time - modern humans.

The evolution of modern humans will require an infinite number of steps (of which only a fraction have been described in the previous section) to be retraced.

Are humans still evolving?

Homo sapiens have been evolving right since the time the species was formed. In fact, the rate of human evolution increased with the practice of agriculture and the formation of cities. We know this from the study of DNA of both modern humans as well as DNA from fossils of our ancestors [Box 2]. As a population, we continue to change genetically. We can't see it happening even though it is happening right before our own eyes.

What is difficult for us to predict though is what we will evolve into. We cannot be sure of the genetic changes in our future populations, nor can we predict accurately our environment beyond the next century or so. Despite this uncertainty, we are unlikely to evolve into another species as this would require, at some point, mating largely restricted within groups of *H.sapiens* that have diverged genetically.

Finally

Heated debates rage around when early humans migrated out of Africa, the routes by which they colonized different parts of the world, the other human species they competed with or hybridized with.

However, some things are reasonably clear - modern humans did not evolve from the monkeys we see today, nor is it likely that modern humans will evolve again from the common ancestors of humans and other apes.

Box 2: How can genetic studies of modern humans tell us anything about our ancestors?
In this section, I describe one way this can be done.
As we know, DNA is not just present in the nuclei of human cells, but also in relatively smaller quantities in the mitochondria - mtDNA. Each mitochondrion contains several copies of mtDNA. Hundreds of mitochondria are found in each human cell. mtDNA have very high mutation rates and therefore, each copy of the mtDNA is slightly different both within a mitochondrion as well as between mitochondria in a cell.

When reproductive cells such as eggs and sperm are formed during meiosis, the mitochondria with their mtDNA are divided between the daughter cells. During fertilization of an egg and sperm, mtDNA from the egg is transferred to the embryo, while that from the sperm is not. So, a human embryo contains nuclear DNA from both the parents, but mtDNA only from the mother.

This means that a mother who has only sons will pass on her mtDNA to her son, but these will not get passed on to her granddaughters, nor grandsons. A daughter, on the other hand, will pass on mtDNA from her mother to her daughters.

Now, using mtDNA sequences from modern humans across the world, researchers construct family trees of humans – grouping those with the most similar mtDNA first. Then the most similar groups are grouped, and so on. In this manner they can then tell which individuals and groups had common ancestors.

Since mtDNA also have mutations, researchers can also count off the number of mutations that separates the different individuals and groups. Then, by assuming the number of mutations per generations, they can actually estimate how far back in time (or how many mutations ago) the different individuals and groups had a common ancestor.

If DNA from fossils are available, they can directly compare it with modern humans to relate the two.

In fact, using these techniques to study the mtDNA from people currently living in India and comparing them with samples from all over the world, we can say that *H. sapiens* migrated out of Africa and reached south-east Asia and Australia via India.