An Introduction to Evolutionary Biology

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Human Evolution

Hi, so in our last discussion, we looked at how life originated on this planet, and then we said that we were going to look at what Happens to be one of the most interesting topics in evolutionary biology for many people, which is how exactly humans evolved. So, whatever you are going to see is primarily based on information from Futuyma and Kirkpatrick. But I have also ended up including input from many other sources. So, if you remember our last discussion, we left at LUCA, and from LUCA, we had the formation of the eukaryotes. Now, of course, between the origin of life and humans, many, many other traits ended up evolving. So, you know eukaryotes formed here; then at some point, we had the formation of multicellular organisms, nerves, and muscles.

So, here I am showing you roughly how many million years ago those changes happened. So, the dorsal nerve cord happened, bones came into the picture, you know, legs and limbs evolved, the amniotic egg evolved, and the placenta evolved. And then, somewhere around 70 million years ago or so, many mammals, including the early primates, They ended up evolving; they had binocular vision, and at some point, the tail was lost about 18 million years ago. And then at some point, you know we had all these apes coming in and about 35 million years ago, these apes, the so-called tailless primates, arose. So, here I am showing you a quick phylogenetic relationship among some of the living apes. And you can see that you know humans are here. We ended up splitting from the lineage that gave rise to bonobos and chimpanzees about 7 million years ago. And this lineage, you know, that finally ended up leading to humans, is what is known as the hominin lineage.

So, these two bonobos and chimpanzees, you know, both belong to the genus Pan. Humans and all these other species, the so-called hominin species, belong to the genus Homo. Now, although it is shown as a straight line here, The hominin lineage actually gave rise to several species, all but one of which went extinct. And that one species that survived was Homo sapiens, which are us. Now, what exactly does it mean to be human? Now, typically this question is asked in a philosophy class, but if you ask it in a biology class, You can answer it in many different ways.

And we are primarily going to look at it in terms of anatomy. Why anatomy? Because much of the information that we initially gathered about, you know, humans and hominin species, They were all through fossil remains, and of course, studying fossil remains in order to understand them. What you need to look at is the anatomy of the corresponding organisms. So, here I am showing you four different species of apes: orangutans, gorillas, chimpanzees, and humans. Now, anatomically speaking, what exactly makes us human? So, what I will do for this is discuss some features of the human skeleton, some features of the chimpanzee skeleton, and we are going to compare them across multiple axes. So, for example, if you look at humans, we are obligate bipeds; you know, locomotion is what we have. Which basically means we walk on two legs. Whereas apes walk on all fours, that is what is called quadrupedalism. And in their case, when you are typically walking on the land, They walk with the help of their knuckles, as you can see over here.

So, this is what is known as knuckle walking, and the other thing that they do is swing from branch to branch. which is what is known as brachiation. And when these guys, I mean chimpanzees and other apes, when they walk, Typically, their posture is semi-erect; they are not erect like us. They are somewhat, you know, as you can see over here in the skeleton; this is what is known as a semi-erect posture. Now, this evolution of bipedalism was a very important feature, you know, in the hominin lineage, and it actually, It is thought that it ended up freeing our hands for carrying and tool use, which were very important.

And also, you know, it allowed us to come down from the trees and essentially walk on the land. which meant that we were exploring a different niche altogether. And this bipedal motion allowed us to be energy efficient in terms of traveling on land for long distances. Similarly, if you look at the human spine, you know that the human spine is S-shaped. So there is one curvature over here, you know, in the thoracic region, and another curvature over here in the lumbar region whereas, if you look at the chimpanzee spine, it is, you know, more or less curved or slightly bent; it is, you know, C-shaped kind of. Now, what is the advantage of this? The primary advantage of that is that this S shape acts as a nice shock absorber. So, when you are walking you know completely erect without the help of your knuckles, then each time you are stepping forward, There is a shock, you know, that is coming to your body through the legs and this spinal cord. This, you know, in the spine; rather, it actually ends up acting as a nice shock absorber. More importantly, this S shape takes the weight of our torso and places it over the center of gravity of the body which happens to be around the pelvic region. And this very nice positioning of the center of gravity allows us to be very stable when we walk upright. Then, if you look at our pelvis, we have this broad but short, bowl-shaped pelvis. Whereas, if you look at the pelvis of a chimpanzee, you can see that it is somewhat narrower, longer, and flatter. Now, what are the implications of this? The implication is that those bowel shapes actually support the internal organs much better, and more importantly, It gives a much better space for the butt muscles, the so-called gluteal muscles, to anchor which allows us to walk much better, particularly in the context of an upright stance. So, that is a huge change and difference from the apes. Then, if you look at our legs and arms in humans, you can see that our arms are shorter and our legs are longer. In the apes, it is the other way around. So, this allows you to know that having longer legs and arms is much better in terms of a striding gait like this, whereas you know for the apes, their longer arms are much better in terms of swinging from the trees. So, it is pretty obvious that you know their skeleton is more suitable for a life in the trees, Whereas our skeleton is more suitable for running and walking on land. Then, if you look at our femur, the bone of the thigh, there is a curvature in this bone. This curvature is known as the valgus angle. And whereas if you look at how this thing operates, they do not have that curvature; this is much straighter and is vertical.

Now, because of this curvature in the thigh bone, This actually ends up bringing our knees and feet directly below our center of gravity. And when that happens, because of it, we are able to walk straight like this. Whereas, if you have ever seen a gorilla or a chimpanzee walking, You would see, you know, it walks like this, like this; it kind of, you know, turns the body like this. And that is happening precisely because it has to continuously adjust the center of gravity. Because its thigh, you know, is not angled the way our thigh is, or the thigh bone is not angled the way our thigh bone is.

So, that is about the femur; you know, this bone here and this bone here. Then if you look at our feet, you know, this is the hand here; you can see that, you know, the finger. This thumb is opposable, and the same is true in the context of the feet of the apes, the chimpanzees. This thumb is opposable, and it is like this. However, if you look at our feet, human feet, then this has actually traveled all the way over here like this, and this big toe, The so-called hallux is non-opposable in humans.

However, human beings, our feet are typically also arched like this, and this arching allows many of us. I mean there are a few people who are flat-footed, but mostly, people have that arch. And that arch actually acts as a shock absorber, allowing us to jump much better. On the other hand, apes are completely flat-footed, but they have an opposable big toe. So, what is the significance? So, the arch, as I pointed out in the humans, acts as a spring, you know, a shock absorber.

Also, you know it allows for better propulsion when you are, you know, putting. One foot and then, you know, putting all your weight on that and putting the other foot forward. So, this springiness allows you to do that much better. I mean, ask a flat-footed person what kind of problems they have. And the second thing is that if you look at the apes, this opposable big toe is very good for them for grasping the branches.

We are not good climbers like that; you know the best we can do is grasp the branches with our hands. They can grasp with all four limbs. Again, highlighting the point that they are much better suited for a life in the trees, We are much better suited to walking on the land. And in terms of the skull, there is something known as the foramen magnum. What is it? It is a hole in the skull through which the spinal cord exits the skull and enters the body.

Now, in the context of humans, that is located centrally over here, whereas in the context of chimpanzees and other apes. That is located at the back of the skull; over here, it is not centrally located, right? So, what is the implication of this? Because this is centrally located in humans, the skull balances much better on top of our neck. So, because of that, when you are sitting like this straight. You actually do not have to put any strain on your muscles or anything to keep the, you know, skull straight like this. Whereas in the context of these guys the apes and the others, if they have to make their this skull straight Because of this position, you know, being much, you know, backward on their skull, the position of the foramen magnum.

They have to put a lot more strain on their muscles in order to keep their heads held high, vertically like this. So, essentially, what happens is that the balance of the skull is much better because of the central position of the foramen magnum. And if you look at our, you know, cranium, We have this large, rounded cranium you can see over here, which gives a lot of space for the brain. And you know we also have a vertical face; a chin that is prominent and our brow ridges; these things are reduced. On the other hand, in the context of the apes, their cranium is much smaller.

So, the you know volume of the brain that can fit inside is much smaller, their jaw is protruding, So-called prognathism and their brow ridges; these things are much, much more prominent, right? So, because of all these changes, in the context of humans, we are able to accommodate a much larger brain inside our skull. which of course is related with our greater cognitive function. Now, just to show you what is the difference between the brain size of humans and other primates. So, obviously, you know all these primates have different body sizes, so you have to scale them by body size. So, here you have the body mass on the x-axis and the brain mass on the y-axis, and you can see that, you know, for all the other primates, it lies on a reasonable non-linear regression; it kind of flattens off. But if you look at humans compared to this regression, we have about 3 times more brain. Three to four times more brain mass compared to all the other primates. And, of course, as you know, this is a huge, huge factor in the context of the evolution of humans. Now, Darwin, you know he had put in a lot of thought about human evolution again.

In fact, although people you know think about the origin of species in a very big way, and of course, You know, for very good reason, Darwin himself was very proud of this book. The Descent of Man and Selection in Relation to Sex, which is obviously entirely about the problem of human evolution. So, Darwin made a very pertinent observation in the context of human evolution. So, I am going to give you the entire quote. As usual, you know, Darwin's sentences are a bit long, so I will break them into multiple parts so that we can comment on them.

So, he says that in each great region of the world, the living mammals are closely related to the extinct species of the same region. So, we already know this was part of his, you know, theory. Then he says that It is therefore probable that Africa was formerly inhabited by extinct apes closely allied to the gorillas and chimpanzees. Makes sense, right? Now comes the inference. As these two species are now man's nearest allies, this means that you know their closest relatives in terms of anatomical features, etc.

It is somewhat more probable that our early progenitors lived on the African continent than in other places. This is superb. Think about it. He is making a direct prediction about where human beings might have evolved. And this is slightly away from what people were thinking around that time because many people were thinking that, you know.

They must have evolved in Asia or Europe because these were the so-called centers of, you know, long-standing old civilizations. But he is using his observations from biogeography to make the prediction that Probably, it was the African continent where, you know, humans might have evolved. And then, in the same paragraph, he makes the prediction that, or rather the observation that, The Earth has certainly undergone many great revolutions, and there has been ample time for migration on the largest scale. In other words, right at that point in 1871, Darwin is making the prediction that look. Migration is going to be a very, very important feature in the whole game.

And, as we are going to see, it has been a major feature. So what do we know about the evolution of, you know, the hominin group? It turns out that the answer is quite a lot. Over the last 20-30 years in particular, an enormous amount of work has happened, resulting in a huge number of fossils. Enormous information has been gathered from DNA data and so on and so forth. So, what I am showing you here is, you know, from the earliest precursors of the hominin group to, you know, So this is the point where the split happens from chimpanzees, which is why you know.

Here you can see the y-axis as time in millions of years ago, and this is what was happening around 7 million years ago. And then all kinds of species happen, and at some point You have this species called Homo erectus coming in, and then this Homo erectus. So, this line, this branch over here in the phylogenetic tree, is equal to this branch. So, this branch continues to this branch, alright. and then this homo erectus, you know, it comes, you know, it basically grows like this, and at some point there is a split over here.

Some people think that, you know, this split over here is called Homo heidelbergensis; other people have ended up contesting that. So, we are not going into that controversy, and at some point, you have modern humans, Neanderthals, etc. coming. So, obviously, this is a fairly complex series of things, and initially, I was thinking that, you know, I am going to make a A longish discussion on the evolution of these various fossil forms, but then I realized that something really interesting had happened. What is that? So, 2024 happens to be the 50th anniversary of the discovery of Lucy.

Now, if you do not know what Lucy is or who she is, it does not matter. That is what this course is for. But you know, just assume for the moment that. There is something called Lucy that is very, very important, and 2024 was the 50th anniversary of that. Now, because of that, there were a series of videos that were released in 2024 celebrating the event, and some of those videos.

I have actually done an excellent job of putting together all the information that we know, particularly in the last 15-20 years. So, you know it is the very latest. So instead of, you know, telling you about this thing on my own, What I am going to do is recommend a series of 4 or 5 videos that I want you to see. So the information content in these videos typically is not very high, but the way they present it is. The people you know who are talking in these videos are mostly the top experts in their field.

Mostly, these videos have been made by some extremely reputable, you know, channels or extremely reputable organizations. So, one can be reasonably confident that whatever he or she is saying is scientifically accurate. Now, why am I saying this in such black and white? That is because when researching these videos, I also came across an enormous number of videos on this topic by channels that. In many cases, I have not heard about, or in some cases, channels that are known to be of a pseudoscientific disposition. So, if you are trying to do such a search on your own, you are probably going to end up with many of those channels.

And then you will end up getting information that may not necessarily agree. With what we are going to talk about here or what these videos will talk about. And that is one reason for which I mean I will not obviously prevent you from searching on your own. But I will request that you take whatever is given in these videos a little more seriously. than some of the other videos that you can easily find on this topic.

So, the other important thing is that I am going to recommend you see these videos in a particular sequence. And the sequence that I am giving you is going to tell you more or less. The story evolved in the sense that not as the species evolved. but in the sense of how human beings, you know, step by step figured out the ancestry of the hominin lineage. So, I personally find that to be a much more enriching and rewarding way of looking at this whole thing rather than you know figuring out that way I gave you that tree. That is also interesting, but this is more interesting to me. The critical part is that the information in all these videos is a part of this course, which means that they might feature in the exams. You really need to see them.

So, the first video is called "The Tool Making Animal." It is an HHMI video, and it starts with the observation that you know. There were many stone tools that people were recovering in various parts of Africa. And then we go to the second video called "Great Transitions: The Origin of Humans." So this is where they talk about the work of the Leakey couple, and they are the people. Who ended up discovering some of the early fossils, particularly the ones that they thought were used to make these tools? So that is a slightly long video, but it is brilliantly made and brilliantly short.

Then the third video, you know, talks about Lucy; it discusses the ancestors of Lucy and so on. And then, you know, sorry, this video is about the discovery of Lucy in 1974. Then, as I told you, lots of things have happened after that. So, this third video, as the name suggests, you know. It is about all these other hominin species that we have discovered in the intervening 50 years.

So it gives you a quick overview of what the tree looks like in 2024. As you can see, this has been commissioned by the journal Science. So you know it is reasonably scientifically accurate. And finally, you know whatever I told you; as you can see, it will tell you about the story as it unfolded. But if you want to now sit back and look at the overall picture, Then this is a brilliant 6-minute or 6-and-a-half-minute video made by the American Museum of Natural History. No voiceover, just brilliant animation, but it gives you the entire story as we know it to date. So, these four should give very nice up-to-date information about what we know about this tree. Obviously, this is not everything; this is, you know, just a very, very broad overview. But this overview should be reasonable as far as this particular course is concerned. And after this, I also recommend this particular video over here: human evolution, evidence of our ancestors.

So, it is a bit long; it is about 2 hours. So, it is not formally a part of this course, but I still want you to take a look at it. Because this gives a very nice, you know, idea about how scientists have gone about getting information from the fossils. How do you look for a fossil? Once you have figured out a fossil, How do you go from one or two bones to the entire reconstruction of how the particular species might have looked? So, very, very nicely done. It is more about how scientists work; you know, it also gives you good information about what they have learned. So, once you look at all these videos, I strongly recommend that you do so before you go forward.

Then you are going to have a reasonable idea of the various fossil forms. So, now what I will do is give you the major milestones in human evolution. and some of these things are obviously covered in the videos that you are going to see. But many of these things are, you know, kind of taking off from the discovery of the fossils. So, the main point of what I am going to talk about here is the various milestones that we are going to discuss now. So, after the divergence from the chimpanzees, as I told you, Many hominin species arose, and very often multiple species coexisted, both in terms of time and in terms of space.

Now, the homo fossils, that is, the hominin line, date to about 3 million years ago. So, that MYA is million years ago, and one of the earliest species was this thing called Homo habilis. which are made of very simple tools, many very simple tools. Then at some point, the Homo habilis arose; I should not say it arose from there.

But this is the next Homo species for which we have very good fossil records. These are the so-called Homo erectus. Now, this is the first hominin species that is believed to have a human-like form. This is the species that is believed to have domesticated fire. They made way more complex stone tools compared to Homo habilis.

And most importantly, this was the species that first came out of Africa. Remember, until this point, everything is happening in Africa. This was the first species that is supposed to have migrated out of Africa. So, starting about 1.9 million years ago, Homo habilis from northeast Africa started migrating and took multiple routes. So, first they came to the

Middle East, and then one went towards Europe while the other went towards India and Far East Asia.

Now, while some populations did that, it is not that all Homo erectus left. Many other populations of Homo erectus continued to live and evolve in Africa. Then, about 0.77 million years ago, which is about 770,000 years ago, there was a second wave of dispersal. Now, the second wave of dispersal, you know, these are the people. Who were supposed to be the ancestors of the Neanderthals and the Denisovans, these are other hominin species.

So, the Neanderthals mainly went towards Europe, Russia, and the Siberian region. The Denisovans mainly went towards the Siberian region. I mean, to date, the only Denisovan fossils that have been found are from that region. Now, about 0.15 to 0.25 million years ago, the so-called modern humans, Homo sapiens, appeared in Africa. That is when we start getting their fossils. Now, these Homo sapiens, I mean, they were characterized by many things. The most important thing is having a very high brain size, so if you have brain volume. So, if you look at the volume of the cranium, this is where the early species Australopithecus were. And as you can see over the course of 3 to 4 million years, there was an exponential increase in brain volume.

So, the modern mean is somewhere over here. So, this very high increase in brain volume is one of the major, you know. Characteristic features of the hominin lineage, not the hominid; sorry, hominin lineage. So, these modern humans, Homo sapiens, which arose in Africa, first spread out of Africa between 0.18 and 0.27 million years ago. However, there were no descendants of these early migrants. So, we cannot find any traces of them in the genes of the extant species. About 70,000 years ago, which is 0.07 million years ago. So, from this point, instead of millions, I am going to shift to thousands.

So, a thousand is KY. So, about 70,000 years ago, genetic data tells us that A few thousand humans migrated to the Middle East from Africa in a single wave. Which basically means this migration happened within a very short span of time. And then all the 7 billion-plus people that you find on the surface of the Earth today, all of them have descended from these 70, You know, these particular human beings who came out of Africa about 70,000 years ago. And that means that the last of the colonization happened about 15,000 years ago, 10 to 15,000 years ago. Which means that Homo sapiens colonized, starting from Africa, the entire planet within a space of about 55,000 years.

Now, for us, 55,000 years sounds like a lot, but please remember that until this point, We were talking about everything in terms of millions of years, right? So, 55,000 years, geologically speaking, is no more than a blink. And we have no evidence that any other animal has ever done such a thing. So, what was the route that they took? So, you know this is the Homo sapiens lineage; they first came out to the Middle East; rather, one group went towards Europe. And you know when they came out over here, the Neanderthals were still around.

So they ended up meeting the Neanderthals; I will talk about that later. Then one group, you know, came to India and then went from India towards Burma, Thailand, and Indonesia. And then finally ended up in Australia about 65,000 years ago. There was another group that went towards Russia, northern Russia, and another group that went towards China. And through China, it went towards Russia, and then about 25,000 years ago, They ended up crossing from Russia into the US; I mean, what is the US these days? North America, basically. And they could do that because the small or narrow Bering Strait, which separates Asia from North America, now.

At that point in time, the Bering Strait was dry. So, these ancestors, you know, were able to cross over into North America, and then they came down the west coast, and then. About 13,000 years ago, they ended up moving towards the east coast, and another group ended up coming down towards Mexico. And then they crossed the Panama, and about 12,000 years ago, they ended up reaching South America. And then they spread slowly over South America; it took them about, you know, 3,000 to 4,000 years.

So, northern South America has had people for only the last 8,000 years. So, essentially, the point I am trying to make is that, you know, this is the part that is known as the old world. This is the part that is known as the New World, and the point I am trying to make is that, you know, 70,000 years ago. They started over here, and about, you know, 12,000 to 15,000 years ago, they ended up reaching here. So, 55,000 years is what they need to cover the entire surface of the planet. Now, remember when all this is happening, when Homo sapiens are spreading across the entire globe, Other hominin species like the Neanderthals and the Denisovans are still around.

So the Homo sapiens ended up meeting all these species and coexisting with them. and we have excellent genetic data to believe that they even hybridized with them multiple times at many places. So this is a map of, you know, western Eurasia, and all these red circles are telling you the places. where it is believed that there was mating and hybridization between Neanderthals and Homo sapiens. So you can see that you know it is over a very large area.

This is Denisova; this is where you have the cave from which the Denisovan species has been unearthed. And yeah, so these are some of the well-known, well-characterized—well, I should not say well-characterized. You know, reasonably characterized based on genetic data, the introgressions that have happened. Between Homo sapiens, Neanderthals, Denisovans, and potentially the Homo erectus lineage. You can see that it has happened many, many times in the past, and people think, based on the data, that Many of these matings that have happened, you know, are more than one hybrid mating that we are talking about. Now, there was a lot of genetic exchange, but after some time, all the other hominin lineages went extinct.

Only one hominin lineage remained, and that is the modern humans we see: the Homo sapiens. So, although all these other lineages disappeared, some of the lineages, particularly the Neanderthals and the Denisovans, We have many signatures of their genomes in modern humans. So just to show you a few representative chromosomes of humans, here are a bunch of genes on various chromosomes. So you know three genes for skin color and some genes for the immune system on chromosome 12. You know genes for reduced cancer risk and adaptation to higher altitude.

So these are some of the many genes that we have in the sapiens genome. The genetic data, which you know, suggest a comparison with Neanderthal genomic sequences. That these are all genes of either Neanderthal or Denisovan origin. So, I will give you one quick example. This is a very famous example.

So we know that the Tibetans you know live at very high altitudes in very cold, low-oxygen environments. Now we know that when the oxygen level goes down, it is really, really bad for the physiology. Which is why mountaineers often have to carry major, you know, oxygen cylinders on their backs. Now it turns out that the Tibetans, even though they live at those high altitudes, They are actually extremely well adapted to that condition. And this is because of mutations in a particular gene known as the EPAS1 gene. Now this EPAS1 gene, which people have shown by comparing it with the Denisovan genome, is actually of Denisovan origin.

So somehow at some point, you know, there was introgression; there was hybridization. And because of that, that gene came into humans and the Tibetan population. obviously there was a massive selection advantage because of which the gene rose to extremely high frequency. So people have compared it with, you know, the Han Chinese populations. And in the Han Chinese population, the frequency of this gene is much, much lower, I mean, so is it in, let us say, European and other populations that also live in high altitudes. Somehow they never ended up getting the gene simply because probably the Denisovans were you know Much closer to where the modern Tibetans are, much closer to where the ancestors of the modern Tibetans were. So while you know when all these things happened, the humans ended up getting to various parts of the world. Obviously, the climate and the local conditions in these various parts varied. And because of that, there were several local adaptations that occurred in the human population. So if you remember, in week 1, we were looking at the variation that we find in human populations in terms of skin color, right? And we never explained why that variation came about or what the reason behind it is.

So what I will do is recommend a video; it is part of the course called the biology of skin color. So it is an absolutely fascinating study about how the original humans who came out of Africa, They most probably had dark skin because of the African conditions and how. When they reached different parts of the world, the local conditions changed, which caused the skin color to change. So it is very nicely done, very beautifully done. So this information is going to be part of the course.

Now the other thing that happened was that at some point, about 11,000 years ago, human beings invented agriculture. It was invented in the Middle East. But then, independently, over the next thousand years, it was invented in many other parts of the world. And in all these parts of the world, people ended up domesticating various crops. They ended up domesticating different kinds of animals.

So if you remember, we have already spoken about how maize was domesticated in South America. So they also domesticated cucumbers, sweet potatoes, beans, peppers, etc. In India, we ended up domesticating millets, black grams, moong beans, etc. So, essentially, people ended up having different kinds of food sources on top of their local conditions in different parts of the world. And when that happened, it led to a much greater diversity in terms of what people were eating, and that itself ended up Putting a huge selection pressure on the local populations, you know, corresponds to their respective environment.

So, we have already seen one such example. So, if you remember, when we were talking about copy number variation, We saw that if you take those populations that are meat-eating, they do not eat too much starch. Then they do not really need too many copies of the salivary amylase gene, AMY1. Whereas those populations, for example, the Japanese populations or the American populations, Which have a much greater amount of starch in their diet, they require a greater amount of AMY (amylase). and therefore, they have a much greater diversity of the copy number variation for this particular gene.

So, that was one example. I will give you one or two more examples from the last few thousand years. There has been massive evolution in terms of the genes that human populations possess. The classic example of such gene-culture co-evolution is lactose intolerance. So many of you might have seen this sitcom called The Big Bang Theory. So, this is one character from that: Leonard Hofstadter.

And if you remember, it is a running joke that this guy is lactose intolerant, which is why he cannot drink milk. And if he ends up drinking milk by chance, he has major flatulence; he is not able to digest it, and so on. Now, very interestingly, although this is supposed to be a joke or comedy point in this particular series, If you look at human adults, lactose intolerance is actually more common than the ability to digest lactose in adulthood. Remember, as babies, all humans are able to digest lactose. If they cannot digest lactose, then they obviously will not be able to drink milk.

And as we know, all human babies start their lives with milk. But it turns out that as we become adults, our ability to express the lactase gene, which breaks down lactose, goes down. And this is not a property of humans alone. It turns out that all mammals are organisms that drink milk, right? All mammals in the adult phase do not express the lactase enzyme; therefore, they cannot digest milk. Good. But the interesting point is that there are some humans who can, right? And obviously, the question is which set of humans can do that and how they are able to do it.

And if you want the answer to that, I will recommend again an HHMI video, very nicely done. Which will again be the information that will be part of the course, where they end up showing how the primary set of people. Those who are able to digest lactose are the ones who, in recent evolutionary history, have taken to dairy farming. So, they had access to milk, and in the presence of milk, There were some selective advantages to those mutations that enabled humans to digest milk. And interestingly, different populations in different parts of the world have independently evolved the mutations and not the same mutation, but different mutations; however, the result is the same. In those places where milk is a major part of the diet, they are actually able to, you know, digest the milk through that mutation. Very interestingly, there are other places where there is a lot of milk in society, but they still cannot digest it. Turns out that in many of those places, they have culturally invented certain kinds of drinks that take the milk and essentially gets rid of the lactose, and you know whatever comes out is lactose-free and therefore digestible even by lactose-intolerant people, I mean, for example, the kumis drink that you find in Mongolia. Okay, so this is about gene-culture coevolution. Now, one of the questions that we are always asked, you know, we as in the evolutionary biologists, are, you know, Are humans still evolving, or have we stopped evolving? Now, obviously, right now, human beings, you know, are primarily Because of our culture and our technology, the pressure on our biology has reduced. However, it turns out that that does not mean that we have stopped evolving. Within the last thousand years or less, there has been a lot of evolution that has happened in humans. And I am going to give you two examples, two very big and well-known examples.

So, the first example is this set of people known as the Bajau people who are found in the Philippines and Indonesia. So, these people are called sea nomads, and as you can see, they live in villages that are in the middle of the sea. So, they are essentially marine hunter-gatherers. In other words, they, you know, hunt fish; they hunt for other things, you know, from the bottom of the sea. and they have been doing this for more than 1000 years without any specialized diving gear or anything.

All they do is put some kind of, you know, goggles on their eyes, and that's it. They do what is known as free diving. They do the diving without using any specialized breathing apparatus. It is extremely well known that they are the best free divers in the world. They can dive deeper, and they can live, you know, longer under the water much longer compared to any other set of human beings on this planet. So, a normal freediver will be able to dive, say, about 4 to 5 meters. These guys will be able to go down 20 meters below the surface, and their ability to hold their breath is much greater. More importantly, they can spend 4 to 8 hours a day, obviously not continuously, but Over the 24 hours, they can spend 4 to 8 hours below water without any major adverse effects. If you and I are trying to do that, then we are most probably going to the hospital. Now, why is that?

What exactly allows them to do that? So it turns out that there are many genetic changes that have happened in the Bajau people. But the major one is a mutation in a gene called PDE10A. And this PDE10A mutation allows them to have a much larger spleen. About 50% larger than other nearby populations, it is a spleen that produces RBCs. So, the concentration of oxygenated RBCs in the blood of these individuals is much greater. There are many other genetic changes as well.

So this is the paper that figured out many of those changes. I will actually recommend that you go to the website for this paper. They have a very nice video where they not only show the Bajau people, but also They also end up giving you very nice information about which other genes have changed in these guys. And because of that, how exactly are the Bajau able to spend so much time below the water? So this is the first one. But as you can see, this is, you know, a kind of situation where an existing trait people have has become better at that trait. It is not really talking about the evolution of a new trait.

So the second example that I am going to give you of contemporary evolution is a situation. Where have people been able to get a new trait, and what is that? So, as you can see, this is sushi; Japanese people, in particular, are very famous for eating this. If you look at sushi, can you see this black wrapper over there? This is actually seaweed; it is called nori. Now it turns out that the Japanese consume an enormous amount of seaweed. I mean, it is an island nation, right? So obviously it is part of something that they can get very easily.

Now, not only in the form of sushi but even in the form of soup and many other things, they actually consume a huge amount of seaweed. Now, normal human beings cannot really digest seaweed, but it turns out that some Japanese can actually digest the seaweed. How can they do that? That is because there has been a horizontal gene transfer from a marine bacterium. called Zobellia galactanivorans and a human gut bacterium called Bacteroides plebeius. And because of this horizontal gene transfer, the genes that can digest the seaweed.

Now it has been transferred into a bacterium that lives inside the gut of the human. And the human beings are now passing this bacteria vertically from parent to offspring. Now, because of this, this particular population and the individuals whose microbiota have this particular mutation, They are able to digest seaweed, which obviously means there is a new character that has evolved. Due to the action of horizontal gene transfer on the microbiota. So, what this is telling us is that human evolution has not really stopped, and we are still able to do new things and very impressive things, even within the last few years, you know, the last thousand years or so. Now, what is the takeaway message from this rather large amount of information? So, the take-home message is that when you normally think about human evolution, The picture that comes to your mind is something like this, right? You had this nice little monkey and at some point you know it started becoming straighter and straighter And then at some point, the tools came in, and then you have this nice bipedally walking human. It is not a linear sequence like that; this is not how it happened. What human evolution is more accurately represented as is this diagram. where there were all kinds of branches happening, There were all kinds of gene exchanges that ended up happening, and finally, You know it is more like a network, a very tangled mess rather than a neat sequence like this.

Now, up to this point, we have seen how humans have evolved both in ancient and recent times. However, evolution is something that is not merely about the past, nor merely about the last thousand years or so. There are several situations in which evolution impinges upon our contemporary lives. I mean, we just lived through the pandemic, right? And if you remember, every few months, or sometimes even faster, We were hearing about new lineages of viruses, right, Delta, Omicron, and God knows what else, right? So that was a situation where the evolution of that COVID virus happened right in front of our eyes, and we paid the cost for that evolution. But even if we do not go along that axis, there are many other ways in which evolution, evolutionary thinking, etc. impinges upon how we live our contemporary lives, and that is what we are going to discuss during next week. See you then. Bye.