An Introduction to Evolutionary Biology

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Week 1 Lecture 2

History of Evolutionary Thought (Pre-Darwin)

Hi, so in the previous lecture, we saw that we were trying to ask what exactly is evolutionary biology trying to explain and we gave the answer that it is trying to understand how diversity of life forms came about and why the organisms are the way they are. And we pointed out that the first part that why the organisms are the way they are is actually supposed to be a part of molbio or genetics, why exactly is it part of evolution? And then we also looked at the quotation from Dobzhansky which says that nothing in biology makes sense except in the light of evolution. And of course, this definition of evolutionary biology does not really make it obvious why somebody would make that big and bold a claim. And then I said that in order to understand why these two things are the way they are, one needs to look at the history of the evolutionary thought in biology. More specifically, one has to look at how this thought about evolution itself evolved over time, how it itself changed over time. So, that is what we are going to do in today's discussion.

One cautionary note though, by the time we finish this discussion, you will start getting an idea of why is it that those two claims were made. However, a formal answer to this question will not come at the end of today's discussion, it will come somewhere may be by the end of the discussion after that. So, basically the amount of material that we need to cover is too much. So, I am breaking it into two halves.

If you remember, we said that there are four major properties of life on earth. We find that there is a lot of diversity of life forms across groups and there is a lot of variation even within groups. And if you look inside an organism, you find it to be really, really complex and all these features that the organisms have, they somehow tend to be related to the environment in which the organisms are found. So, there is an environmental specificity to the features of organisms. Now, obviously, our alien will not be the first you know person to observe all these properties.

These properties have been observed by human beings from the dawn of civilization. And of course, people have asked the question, one of the primary questions of humanity is where exactly did all this come from, all this tremendous diversity. And turns out that every civilization have had their own so called creation story or creation myth. So, for example, if you look at the Indian scriptures, different ancient scriptures of course, have very different views. So, for example, the Rig Veda, you know in different parts of the Rig Veda, it talks about Hiranyagarbha, which is the golden womb or the golden egg or the Purusha as the being from which creation happened.

In fact, one of the you know suktas, the so called the Nasadiya Sukta of Rig Veda even goes on to say that look, it is not even possible for anyone to know where exactly creation happened and who made it. There are other you know scriptures like for example, the Shatapatha Brahmana, which says that it is Prajapati from whom all the creation comes. The Upanishads, you know, there are 108 of those. So, depending on which Upanishad you are looking at, they have given the role of creator to the so-called Atma, the Purusha, the Brahma and so on. Most of the Puranas mention Brahma as the primary creator.

However, the major points to note in the context of the ancient Indian way of looking at creation is that there was a creator or a group of creators and whatever forms we see, you know, the human beings, the animals, the plants, all were created simultaneously. And there are certain ways of thinking in the ancient Indian scriptures, which assumes that there are multiple cycles of rebirth and the same soul, the so-called Atma, that can actually undergo different births in different forms, including humans and animals and plants. So, and the getting away from this cycle, continuous cycle of birth and death is the so-called attaining the salvation or the moksha. Now, as I said, we are not the only ones to think like that, the ancient Egyptians had similar views, pretty much everybody had similar views. So, one group of people whose views of course, have played a major role in terms of our understanding of these things are the Greeks.

So, again there were many, many philosophers, but the one of the most influential philosopher in Greece was Plato and after him was his disciple Aristotle. And Plato and Aristotle they talked about the so called scala naturae or which later you know in medieval period in Europe became called the great chain of being or the G C B. So, what is it? Basically it says that if you look at all the tremendously diverse forms of life on earth, you can actually divide them into a hierarchy going from less complex to more complex and this is what the hierarchy that they talked about. So, right at the bottom were the non-living organisms, sorry non-living you know entities, the so-called minerals, above them were plants, above them were animals, above them were humans. So, humans were supposed to be different from animals and then above them were the angels and right at the top was God.

Now, of course, you know this is what the Greeks said and then later people they ended up making finer distinctions within each category. So, among the plants this talked about simpler plants and more complex plants, among the animals simpler animals and more complex animals and so on and so forth. Now as a very broad brush way of arranging all the diversity this kind of works, but this is explicitly assuming that the order of this classification is fixed. In other words all organisms they are in you know one category or the other and once they are there they are not really changing. Now as a very broad stroke classification this you know might work, but given that we already saw there are millions and millions of organisms, it is very difficult to fit them in just these four or five categories.

So, obviously this way of looking at things although it was very good for the ego because you know we had humans just below the angels but otherwise practically speaking this was not very useful. So, ever since you know the ancient Greeks people the so called taxonomists they have been trying very hard to come up with better schemes of arrangements and of course there are many many taxonomers whose names can be mentioned. But here I am telling you about perhaps the most famous taxonomist of you know any time Carolus Linnaeus. So, this was a Swedish biologist he was around in the 18th century and Linnaeus he gave what is known as the binomial system of classification that is for each organism it had a generic name and a specific name, but his overall system of classification was much much more involved. So, this is the kind of you know ranking system that he came up with.

So, right at the bottom you know he took placed a particular group of organisms what he called species. Then species which were similar to each other were grouped as to form a genus. So for example here we are talking about a species of beer and all bears they form the genus Ursus. Then beer like animals you know pandas and guacoalas and everything all of them come together to form the higher grouping called family. Then above them were a higher grouping called order, then class, then phylum, then kingdom and so on.

This is the normal taxonomic system that you read in textbooks. Now the interesting thing to observe over here is that the moment you are able to form some kind of a classification like this, it straight away tells you that there is some kind of a connection between organisms. It is not that things are so random that they cannot be grouped at all, you can actually form these kinds of very nice you know nested hierarchies of characters or features. However, the way you interpret this can you know obviously depends on what is the backdrop in which you are trying to do this. So, for example, you know if you look at Linnaeus he proclaimed that there are as many species as the infinite being which basically means God produced diverse forms in the beginning.

So, essentially although there was some way of classifying all this diversity, Linnaeus's point was that this essentially reflected what God did and therefore, there are two corollaries which are coming from this particular claim. One was that no species ever went extinct, all species were exactly on the planet the way the God created them and secondly after God created them there was no change you know since the origin. Now this way of looking at things was also you know it influenced another branch of science so called anatomy which is essentially studying the inside of the organisms. So again there were many many anatomists who contributed to the field. I am just talking about a very famous English anatomist called Thomas Willis.

So he was also a very famous doctor and he actually made a lot of contribution in the study of diabetes. So that till some point diabetes was actually known as Willis's disease. However, apart from looking at humans, Thomas Willis also looked at the comparative anatomy of brain in many many groups of vertebrates and there were other people who looked at you know for example, the circulatory system, the excretory system, the muscular system and so on and so forth. Now all these comparative anatomists, one of the major observations that they had was that there was an underlying similarity to the anatomical structures across groups. What do I mean by that? So suppose I take a human and then I take let us say a horse and then I take let us say a bird and then I take let us say a you know fish.

In all these organisms you will find some organ which is beating and that organs beating is actually leading to some kind of a fluid being passed through the various parts of the body through certain vessels you know what you call them blood vessels or whatever. So, this kind of similarity was not only there in the circulatory system, it was there in the nervous system, it was there in pretty much any physiological system that you chose to look at. And the way these anatomists interpreted that data was that this reflects the God's will, this reflects the great chain of being or the you know systema naturae that we talked about. And therefore, for them the fact that so many diverse organisms still had the same kind of plants essentially was a manifestation of God's will. The other set of people who were very you know important and influential during this time were the physicists or to be more specific, those physicists who were using the advances in physics to you know specifically optics to look at the fine structures of organisms.

So, all of you have heard of this you know Dutch microscopy person called Leeuwenhoek, he was one of the first people to observe the minute structures. Another physicist who played a massive role in this was this man called Robert Hooke, the British physicist. And he made a microscope and he actually looked at various organs of small organisms. So for example, here is Robert Hooke's drawing of the head of a drone fly and you can see how intricate this entire structure is, right. And this was not the only thing, there are many, many others, you know, microscopic structures that they looked at.

All of them were complex, all of them were intricate and based on that these people came to the conclusion that given that even simple organisms can be so complicated, can be so intricate suggests that there has to be a designer, a creator who has created these things. Otherwise, how do you explain such simple things as flies to have such complicated structures? So, this actually led to a field called natural theology, which was trying to prove the existence of God not through revelations as you find in scriptures, but through these kinds of scientific and natural observations. And the field of natural theology kind of reaches one of its top points with this person called William Paley, who was a English philosopher and clergyman somewhere around the late 18th, early 19th century. So, Paley made a fantastic argument. So, what he said is that suppose you are walking on a road and suppose you end up seeing a watch lying on the road and right next to that is a stone, the way you see here.

Now, when you are seeing something like this, then if somebody asks you, you know, why is the stone there or from when is the stone there, you do not really have a very good answer in the sense that for all you know the stone might have been there forever, right. It does not really need any special explanation. But if you look at the watch and you figure out how complicated, how intricate the structure of the watch is, then you realize that the existence of the watch needs an explanation. The existence of the watch presupposes that there was some kind of a designer, some kind of a watchmaker who ended up creating these various parts of the watch, who ended up putting them together in a specific way such that the function of the watch that is telling time kind of comes out of all these inanimate objects. In other words, if you have a watch, then it implies that there is a watch maker and similarly, if you have anatomical and physiological complexities, then that automatically implies that there is a design and the presence of a design implies that there was a creator.

Now, this argument looks like a very, very strong argument and actually you know it was something that convinced many people including Darwin for some time. However, not everybody got convinced and there were various features of various kinds of scientists who were trying to examine these positions. Now, what positions are we talking about? Just a quick recap. The three positions in explaining biological diversity that we talked about are A, there is a creator, B, no species ever went extinct and C, no species ever changed since their origin. As I said, not everybody believed in these things.

And a major challenge to this way of thinking actually came from the paleontologists. Again, several paleontologists contributed to this, but one particular person was very, very influential. His name was Niels Stensen and the name was Latinized to Nicholas Steno. So, he was a Danish polymath, which basically means he contributed to multiple subjects, two of the major of which was evolution and geology. Very interestingly, Nicholas Steno was also a bishop of a church and he was actually beatified by the Roman Catholic Church, which essentially means that he is on his way to become Saint Nicholas Steno.

So, all those people who think that science and religion cannot coexist, here is an example. Now, Steno was a very accomplished anatomist and somewhere in Italy, they, was it Italy, somewhere in Europe, they caught a huge shark and the head of the shark went to Steno for observation. Now, he obviously looked at the shark at great detail, published his observations, but he also noted something very peculiar. So, in those days, there were these you know stones, triangular stones, you know, these kind of stones. These stones were found all over the place and due to their shape like tongue, they were known as tongue stones.

Now, while looking at the head of this shark, Steno suddenly noted that the teeth of this shark actually looks very much like these stones. And he made the very, very bold claim that these stones, the so-called tongue stones, they are actually remains of organisms which are long dead. Now, these kinds of fossils, you know, of the kind of tongue stones, they were being found all over the world. But the problem was many of those, for example, you know the kind that I am showing you over here, these look exactly like seashells. However, these kind of things are actually found in the mountains.

So, if you are claiming that these kinds of things are actually remains of organisms long dead, then how do you reconcile the fact that they are being found in mountains whereas these are clearly marine forms? So, Stino actually came up with a very bold hypothesis. He said that perhaps what we see as mountains today, at some point in time, those were actually below the sea. That is why you find remains of sea organisms on mountains. So, this was very influential and the paleontologists, they basically started looking for more and more fossils of this kind. Many, many you know paleontologists contributed.

However, the one that I am showing you was you know perhaps the most famous paleontologist called Georges Cuvier. He was a French anatomist, a very interesting person, made lots of contribution to biology. And among other things, he ended up studying these massive elephant-like structures called mammoths and also similar organisms called mastodons. So, he looked at their structures and came to the conclusion that these are basically elephant-like structures, elephant-like animals, but more importantly he came to the conclusion that look these are massive organisms, right. If these organisms were still around, human beings would have noted.

These are not organisms whose just by the virtue of their size, they cannot be just hidden somewhere, you know, away from human eye. Therefore, Cuvier came to the conclusion that these fossils belong to species that are no longer found on earth and therefore, the corollary was, the interpretation was that species can go extinct. This obviously leads to a theological problem because the great chain of being that hierarchical classification that I talked about, Scala Naturae, that is supposed to be God's will, that thing is supposed to be perfect. Now, if that thing is perfect, then obviously extinction is not possible. So, the fact that you are saying extinction can happen implies that the great chain of being is not perfect and therefore, it is not something that is ordained by God.

Very interestingly, although Cuvier came to the conclusion that species can go extinct, he still did not believe that species could change over time. He actually thought that species are being constantly formed and they are being constantly destroyed. So, you know a kind of Indian system of you know creation, destruction, creation, destruction, continuous cycles of the same. So, if we look at the three positions that I talked about, one of these positions with the work of people like Cuvier essentially went out. What happened to the other two? Most importantly, what happened to this position that no species changed since their origin.

As I said, there were lots of people who believed in it, but not everybody. So, for example, if you look at the ancient Chinese system of knowledge, the Chinese philosophers particularly the Taoists, they believed that the humans, nature, heaven, all these things are constantly interacting with each other and all these things are constantly changing. Similarly, you know there was this famous French biologist called Comte de Buffon, he studied all organisms around particularly the vertebrates and came to the conclusion that if you look at all the four-legged animals, it seems that they have come from only 38 ancestral forms and no more. Therefore, obviously the number of four legged animals was way more than 38. Therefore, his conclusion was that species could change.

However, his theory was actually a very you know ad hoc kind of a theory, he did not really have good systems by which such changes can happen. And the credit for coming up with a first coherent theory of change in species actually goes to the French biologist Jean-Baptiste Lamarck. Now, all of you would have talked or heard about or read about Lamarck during your school days. Whenever you say Lamarck, the typically the picture that comes to people's mind is this, right. You had giraffes and then the giraffes, they stretch their necks in order to you know reach the top branches and the neck kept on getting you know stretched and all this stretching thing was a heritable change and after some time you only had giraffes with long necks.

Now, this actually is a very small portion of Lamarck's entire theory. So, what Lamarck actually said was a bit more and you know complex and a bit more satisfying than this. So, Lamarck's position had three or four components. So, the first thing that Lamarck said is that life is continuously being generated from non-living matter. So, suppose you have time on x axis, then each one of these red dots is an independent instance when life has generated.

Life has formed spontaneously from non-living beings, non-living entities. His second point was that there exists a master plan according to which organisms change across generations towards greater complexity. So, you can see that this is very much like the you know Scala Naturae, the great chain of being except that there the Skela Naturae was a scheme of classification. Here he is talking about a master plan and he is explicitly saying that organisms species can change from a lower level of complexity to the higher level of complexity. So, basically what he proposed as a master plan looks something like this.

So, right at the bottom were this you know simple single cell organisms amoeba and all those that is what he called infusoria. Above them were organisms like jellyfishes, above them were slightly more complex organisms like worms, above them were insects, above them were molluscs, above them were vertebrates and so on and so forth. So, basically a nice progression of course, you know topped by human beings right at the you know apex. So, this was his master plan. And then he suggested that all organisms are constantly being subjected to two different kinds of forces.

The first force which he also called the complexifying force, this moves organisms across generations towards greater complexity along the master plan. So, remember I showed you this thing, this stuff at the bottom. So, this is where we have time on x axis and you have spontaneous generation happening and each time a spontaneous generation happens that lineage actually travels across these inclined lines and you can see that this color is changing slightly, it is becoming from lighter to darker as we go up. So, this is what is showing that the species is constantly changing according to a given master plan.

Similarly, this is a second lineage which has started over here and then as time progresses this keeps on changing like this.

Now, suppose we are here at this present point right when I am showing this with an arrow. So, what is happening at this point? All the organisms or all those lineages which started later they are still at a lower level of complexity. Whereas, all the organisms which started earlier they are at a higher level of complexity and at this point in time in present, we only have this snapshot, whatever is being shown on the right hand side, all these points and this according to him is what explains the enormous diversity of forms that we find in you know nature around us. Now, why should there be similarity across groups? Because all of them are following the same master plan right and because the master plan is the same it is just that different lineages are in different points along that master plan and therefore, although there is an underlying similarity, there is some also some amount of underlying difference. So, in one shot using this complexifying force, he was able to explain both biodiversity and the similarity.

However, he said that there is one more force which is acting on organisms. So, this in some sense this first force the complexifying force you can think of it as the also called the vertical force. He also talked about what he said as adaptive force or a horizontal force. What does that mean? So, he said that organisms are also being acted upon these adaptive forces which are making the organisms adapted to their environment. So, this you know the complexifying force is what is taking the organisms or the lineages across the great chain you know the master plan and on top of that each generation the organisms are facing pressure from the environment.

And this adaptation to the environment is happening because of two mechanisms. What are these two mechanisms? So, both these mechanisms demonstrated over here, one is use and disuse of organs, the other is inheritance of acquired traits. So, what do I mean by that? So, suppose you have a bunch of giraffes, these giraffes they are let us say in an area where much of the food is at the higher level. So, these giraffes they need to stretch their necks in order to reach that food and therefore, by the time these young giraffes become old giraffes within the same generation, their necks due to repeated use is going to get longer, it is going to get stretched. Of course, there will be some other organs which due to less use can become less you know can shrink in size.

Now, Lamarck also suggests that all organisms in the population are not going to experience this force, you know, the use of the organ to the same degree, right. Because some will find food lower, some will find food you know at a greater height, so some will have to stretch their necks less, some will have to stretch their neck more. So, there will be a variation in how much use and disuse of the organs is happening. And then when these guys are reproducing, they are going to take these traits that they have acquired, the longer neck let us say and they are going to pass it to their next generation, to their offspring, to their babies. And when this keeps on happening generation after generation, then the necks of the future generations, they are going to be stretched right at birth.

And therefore, starting from short necks, you will end up getting long-necked organisms, right. In other words, he suggested that whatever trait is being acquired by the organisms, they will be passed to their next generation. Now, by doing this, Lamarck actually ended up explaining two other observations that we had made. One is the diversity within a group. As I said, different organisms in the population are experiencing different levels of use and disuse and that is what is creating the diversity within the groups.

And obviously, over time, you know whatever organ is being used more to get a better mileage out in that particular environment, that particular organ, its structure is going to change in a direction that it makes it more suitable, more adapted to that environment. And in this sense, the theory that Lamarck came up with was also explaining how the organisms are getting adapted. In other words, the four major properties of life on earth that we started with, all four major properties of life on earth were getting explained by Lamarck's theory. The tremendous diversity of life forms is happening because of two things. A different lineages have arisen at different times and different lineages have progressed to different degrees according to the great plan and at any given point of time we see all of them together and therefore, we see this tremendous diversity.

Why is there variation even within groups? Because of the use and disuse being you know happening to different organisms at different rates. Why is the complexity? The complexity is because again you know the organism A. there is the plan, and B. the organisms are you know doing use and disuse which is again increasing the inherent complexity And why is there adaptation, why are the you know features of the organism environment specific simply again because of the use disuse coupled with the inheritance of acquired traits.

So, as a theory this was an excellent theory. Now of course there are lots of you know loopholes in that that is a different ball game, but this was a good theory because it was explaining a lot of observations in one shot. And as I said this is explaining all the major properties of life that our alien would have noted. Interestingly when we talk about Lamarck or we use the term Lamarckism, we do not talk about all these aspects of his theory, we only talk about the inheritance of acquired characters, right. And interestingly that was not even his own idea. So, at Lamarck's time inheritance of acquired characters was the primary notion, was the dominant feeling about how you know characters get passed on from generation to generation.

And therefore, Lamarck just took it and put it in his theory because he needed some form of inheritance that is it. His main contribution were all that master plan and you know two kinds of force etcetera, etcetera. People have forgotten all that and they remember Lamarck only for this inheritance of acquired characters, which is very sad because you know his overall contribution is much much greater than this. But then if his theory was explaining so much stuff, why did it not get accepted? So, turns out that there are multiple reasons for this. One of the reasons that many historians of science have pointed out was actually Cuvier.

Remember, this Cuvier is the person who said that extinctions happen. Now, Cuvier was way more famous and way more powerful than Lamarck and therefore, certain authors have pointed out that Cuvier actually made sure that Lamarck's theory was essentially ignored by the scientific field. Of course, later authors have you know put a question mark on this claim and have said that Cuvier he was powerful, but he was not that powerful. So, the other major reason for which Lamarck's theory did not get traction was because everybody somehow felt that inheritance of acquired traits is the key feature of that theory, which was not the case, but still and yet inheritance of acquired traits is something for which there was absolutely no you know evidence then. Nowadays we have a few evidence that is what we will talk about later, but at least around that time I mean for example, when people looked at blacksmiths, the kids of blacksmiths did not come out full of muscles, they came out you know like this little chubby baby that you see here. There were obviously many experiments that were also done, which more or less ended up showing that there is no reason to believe that acquired traits are inherited.

And that is why people more or less disregarded Lamarck's theory. Interest in Lamarck's theory actually became much you know greater at a later stage, we will talk about that when we reach there. But when it was published by and large Lamarck's theory was completely neglected. So, if that be the case, then whose theory worked? Who was able to convince the world? As we know that was this man Charles Darwin. So what exactly did he do? That is what we are going to discuss in the next discussion And hopefully by the time we reach the end of that video, I will be able to convince you why is it that evolution turned out to be or rather you know the way Charles Darwin thought about the process of evolution that ended up having ramifications not only in the field of evolution, but in many many areas of biology. You can already see some you know aspects of that, you can already see that you know things like anatomy, paleontology and physiology everything is already coming together in terms of trying to answer this simple question why so much diversity.

But when Charles Darwin came up with his theory, the scope of this entire thing became extremely large and it essentially ended up affecting every single area of biology. How did that happen? In what way did Darwin's theory prove to be so broad and so deep? All that next discussion. Bye.