Course Name: I Think Biology

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W7L35_Evidences of Evolution

For evolution to act on within a population, there needs to be variation in that particular population. There has to be, those variation has to be heritable and those population will say some members will survive, some members will die, but as a result, there is also differential reproduction. So, all these kind, these three conditions are needed for evolution to happen. And in fact, for natural selection to operate, these are the three conditions which are required. So, when I say that evolution happens, it is through natural selection, you know, in which evolution works, if there are these three conditions are met. So, evolution can happen in different ways.

One is through natural selection, and that is the most popular way which we know of or which we often talk about. And but there are other ways in which evolution can occur. That is through mutation and other ways are genetic drift and gene flow. I am going to be talking about all these processes in the successive lectures.

So, I am not going into detail right now. Let's actually look at evidences of evolution. How do we know that evolution is actually occurring? We can actually observe things in nature. We can look at common ancestry that is homology in nature, or fossil records and biogeography also gives us ample evidence of evolution. And I am going to be going into details about each and every one of these.

So first, let us take a direct observation through which evolution we can observe evolution. So this is a story about Staphylococcus aureus. This is a bacteria, which is found on skin and nasal cavities and so forth, so on and so forth. But this is a story about how that bacteria over time developed drug resistance. And this is an evidence of evolution and I will explain how.

So earlier, this is around 1943, they discovered Penicillin, which was used as a very, very effective antibiotic against Staphylococcus aureus or Staph aureus to kill Staph aureus. So this was effective because Staph aureus was not exposed to Penicillin and this antibiotic worked fairly well. It killed the bacteria. But then within two years, this bacteria developed resistance towards this antibiotic, because there was, it was so popular that everywhere everybody was using, you know, in hospitals, people were using Penicillin and the bacteria developed resistance. So then, scientists discovered one more antibiotic known as Methicillin.

And of course, you know, this antibiotic was also very effective against Staphylococcus aureus. You have to remember when I am talking about Staphylococcus aureus, there are a lot of Staphylococcus which are just normally present on our body, but some are pathogenic or disease causing. So the antibiotics are against those disease causing bacteria. So Methicillin was produced and of course, people were very happy because it killed Staph aureus and but again, as expected, or not very surprisingly, there were quickly, there were Methicillin resistant strains of this Staphylococcus aureus. So that is known as MRSA, MRSA, that is Methicillin resistance Staphylococcus aureus.

Okay, so what that meant was the bacteria also became resistant to even this new antibiotic, which was Methicillin. Methicillin basically targeted the cell walls of this bacteria, but this bacteria developed an enzyme which prevented, you know, which developed resistance towards this antibiotic, which did not basically, which did not allow it to be affected by this antibiotic. So this is how drug resistance is developing. And this graph here is a demonstration or a summary of what I just told you, how drug resistance in bacteria has been developing over the years. This is a slightly older graph.

I am sure there are newer graphs, but the trend is similar to, will be similar to what I am showing right now. So on the x-axis, there is year and on y-axis, there is annual hospital admissions with MRSA. In thousands, that means that they have recorded how many people were administered or admitted to hospitals with MRSA infection. So they were not responding to Methicillin antibiotics also. So in 1993, there were, you know, less than 20, hardly any cases.

But you can see over the years, number of people getting admitted because no antibiotic or Methicillin has not worked has been progressively increasing. This is in thousands. Okay So you should remember it is not in hundreds, but in thousands. So as in 2005, the, you know, number of people who are getting infected or getting hospitalized with MRSA infection was close to, you know, 400,000 cases. So now the question is, how did bacteria get resistant so quickly? So this is the question for you to think about.

Let us say that some of the bacteria are resistant to particular antibiotic. So the question is, how are drug resistant strains of bacteria have evolved through natural selection? Let us imagine a scenario where there are hundreds of hundreds of bacteria and you apply an antibiotic and say 80 of them get killed because they are not resistant, but 20 of them manage to survive. It means that they might have certain trait or a feature or a character in them, which allows bacteria to be resistant towards this particular antibiotic. What does that mean? So it might have an enzyme which is blocking the antibiotics or which is actually manages to escape this antibiotic or it might have certain genes which hence code for other proteins, which again confer resistance to antibiotics. So these 20 individuals of this bacterial strain do well and they pass on this trait to the successive generation.

So this is what is meant by these bacteria have evolved resistance by natural selection. So this is, remember that this is just one process in which evolution can act on. There are other ways in which evolution can act on and I will come to that later. Another evidence of evolution is homology. Here I am going to talk about structural homology.

This is something if you have taken biology in your class 11th or 12th, you would all have studied something like this. You would all have known about structural homology. But regardless of this, this is quite commonsensical. So let us take up limbs of different mammals. So here is a human, human, cat, whale and bat.

They all perform different function. Human hand is for a different function. Cat limb is used for walking. Whale, you can call it hand, but is converted as flippers, which is used for swimming. And bats use their hand for flying.

So there are various functions that different mammals do, but their structures are very similar. So these are color coded. I am not going to spell out these names here, but all of them are color coded across different mammals suggesting that these are exactly same kind of structures, which of course slight modifications, but these are the exact same structures which is present in various mammals. And what this suggests that all of them share similarities in their structure. Right? And that is an evidence of evolution that, okay, these are all related groups of animals and they share similar structure, though their functions are very different.

One more example is that of leaf modification. Again, you will be familiar with these examples or you would have seen these kinds out in nature. The leaf has been modified as into pitchers for, this is a pitcher plant. And actually this leaf has been modified into a jug like structure known as a pitcher in which liquid like an enzymatic liquid is present and that helps to digest various small things like insects or even sometimes geckos, stuff like that. So this is a carnivorous plant and this is an example of leaf modification.

There's one more example of leaf modification is another insectivorous plant known as Venus flytrap, where it's modified in such a way where this is a Venus flytrap. And they say that these are the two flaps. And if an insect walks in between this leaf, there are hairs on these leaves. And if say, for example, a fly is walking around on this leaf, if it touches more than three hairs, the leaf quickly closes, thereby trapping that particular insect. So this is again a leaf modification.

Regular leaves don't do this. So again, a leaf modification. Poinsettia is something which many of you might have seen. These are one of the decorative plants. Right? These are again, these are not petals, but these are bright leaves that resemble flower petals.

Again, one more modification. Cactus again, the leaves are modified into spines. So these are various examples of again, structural homology. All against leaf is the same common structure, but it has been modified to suit different serve different functions. One should not confuse this with another aspect called convergent evolution.

I'll explain this. But basically, what it means is that you have similar features, but different ancestry, these are not related group of individuals, they have different they come from different ancestors, whereas here, they're all share this same ancestor, they all of them are mammals, or all of these structures are coming from leaves, right. So this is different from convergent evolution, where you share similar features, but they come from different ancestry. So to give you an example, these are these cute little mammals are sugar gliders, which are found in Australia. These are basically marsupials. Think about kangaroo, when you think about marsupials.

So these are pouched mammals. And when they go from one tree to another tree, they glide, you keeping their kind of arms like this. So these are sugar gliders. A very similar mammal is a flying squirrel. This is a placental mammal found in North America.

And these are flying squirrels. So outwardly appearance are very similar, but they have different ancestry. So one is a marsupial or a pouched mammal and there is a placental mammal. So this is an example of convergent evolution where, because of I mean, both of them glide, so because of, you know, presenting being present in similar niches or similar ecological conditions, they have evolved certain similar traits, okay, convergent because they have converged on similar features or functions, though they come from different ancestors. Alright, one more evidence of evolution is the use of fossil record from comes from fossil record. And this again, you all might have already known that fossils are missing link for, you know, evolution to say that, okay, there is some commonalities between two different organisms.

So it is almost like a, by finding fossils, you can kind of fit in a zigzag puzzle and see what is the link between the current existing organisms and extent or organisms which are no more, what is the link between the two. So let us take up an example here. This is, so the question is, what can fossil tell us about whale and dolphin origin? So this is living cetaceans, cetaceans are a group of animals where whales and dolphins belong to. So this tree, I will explain again later on, this is known as a phylogenetic tree. That means that it describes the relationship between various organisms and how old or what is the timeline in which, by which they evolved.

Okay, so, so this is on here, it is millions of years ago. Okay, when did they evolve approximately? And what is the relationship between various other animals? Again, these are color coded in various animals here. So living cetaceans, that is, you can think about this as a whale, you know, there is some kind of a pelvis structure here, colored in purple. And then you can see that across various different animals, some which are present, existing things like hippopotamus, or some things like pakicetus is an extinct animal, also seem to have certain similar structures. So now you can ask, okay, what is the connection between a whale which is an aquatic mammal versus something like a pakicetus, which is or even for that matter, deer or pig or other even toad ungulates, which are completely terrestrial? Is there any connection at all? Why am I showing a phylogenetic tree which seemed to link all these animals together? So in fact, people have found that whales are indeed whales originated from land mammals and related to hippos and other even toad ungulates.

So if you look at their skulls and various other bones, you will see that there are certain similarities and certain changes which you can track across millions of years through these fossil record. So let us look at pakicetus. This is, of course, this is a fossil. And this is kind of a constructed cartoon representation of pakicetus.

It existed, it lived 50 million years ago. It is named as pakicetus because we found fossils in Pakistan and other areas nearby. So here, in its skull bone, you can see that the nostrils are closer, you know, at the front of the skull. Whereas in this fossil, which are 25 million years ago, nostrils have moved up at the middle of the skull. And here today in the present day existing gray whales, you can see the nostrils have moved further up at the top of the skull. This is something fantastic, right? Because it shows how present day existing animal, what are the adaptations which to be living in water, what is the kind of adaptation that it might have undergone over time? just as simple as nostril, you know, how the movement of nostril from, you know, closer to the front of the skull to the back of the skull.

It has happened over millions of years ago, and people have been able to track this with the help of fossil record. And these are some of the various adaptations for aquatic life. So they had, they have uniquely shaped tympanic bone, that is the ear bone that protects the ear to hear underwater. And the nasal opening is not at the front of the skull, but it is at the back of the skull. And elbow, wrist and finger bones are enclosed in a flipper.

So you can see that here, all the parts are not kind of as elaborate as it is in other angulates, but everything is enclosed in the, in the flipper. And also, and the flipper of course helps in swimming. right? And it has a reduced pelvic bone, because it is no longer required for walking or it has rudimentary pelvis, no longer whales do not, no longer walk but swim, so they have reduced pelvis. So you can see by fossils, fossils show an evolutionary change that have occurred in various groups of related organisms. So fossils are a very, very cool way to kind of see that evolution has occurred over time.

Okay, so the last evidence, which is, which might be somewhat new to you is called biogeography, evidence through biogeography. It simply says that, how do various animals and plants, where do they live in the present day and how did they get there? Okay, so I will come to an example. By the way, both Wallace and Darwin popularized this concept called biogeography. They believed in this and they had great knowledge about, you know, continental plates and how various organisms are distributed across the earth. So basically, the earth has these different continents, they, they are on these plates, right, and they slowly move over time.

And if you can see here, around 225 million years ago, all the continental plates were kind of together, and that is known as Pangaea. And if you look at later on, around 150 million years ago, those are, those plates kept moving away from each other. So there is Laurasia and Gondwana. So you can kind of roughly see different continents here, which are being separated. And 100 million years ago, you can see that many of these continents because of drifting of plates, because of plate tectonics, these have drifted apart and you can see distinct, you know, countries or continents, what we see in the present world here is basically this is this is what is currently today. right?

So what is this to do with how animals and plants are distributed? So let us say, a lot of animals and plants evolved around 300 to 400 million years ago, right. So they were distributed all over the place here. And then these continental plates moved later on, right. So their distribution, you might see that it might explain how they were present earlier, where did they live earlier and what is the current distribution.

So I will give you a concrete example. So let us say distribution of marsupials, we are again going back to marsupials, you know that kangaroos are good example of marsupials. So they are present in, of course, Australia, and, you know, some parts of South America and some parts of North America and Central America also. So that is the distribution of marsupials today. but Earlier in Jurassic period, that is 160 million years ago, the landmasses were quite differently arranged.

And you can see that these two were connected. And this was one continuous landmarks. And you can see that marsupials are distributed in these, these areas. And over the years, so 70 million years ago and 60 million years ago, when the these plates are moving, you can see the distribution is, it is like this and currently it is distributed in where we see them today. So how is this an evidence of evolution? Because you can trace back, where did they come from? Where did these organisms, you know, you might think that, okay, there are marsupials in Australia, but there are also very, very similar marsupials in South America, you can think that how is that even possible for very similar animals to live in two different continents, which is not connected by land, right? So it is impossible for them to kind of go from here to here. But when you look back and when you look at what was the history of earth several million years ago, and you can see that the landmasses were connected, then you can easily explain the present day distribution of plants and animals by looking at biogeographical patterns.

And this is yet another example of evolution. Here is another question for you. So dinosaurs originated around 250 to 200 million years ago. So would you expect the geographical distribution of early dinosaur fossils to be broad, that means spanning many continents or narrow with only few, which are present only on few continents only? So think about this. You do not have to answer right away. Think about this and we will come back to this in an assignment.

Okay, so this brings us to an important question. Why do we have to care about evolution? Does it even matter to us in our day to day lives? Yes, we all know that evolution happens, but how does it affect us? Does it even affect us or do we have to really care about evolution? A famous Ukranian American geneticist known as Theodore Dobzhansky famously once said that nothing in biology makes sense except in the light of evolution. And we can see this repeatedly throughout various kinds of biology, whether you are studying ecology or behavior or if you are studying molecules or neurobiology, whatever you might end up studying, all of them are held together by understanding of evolution and you can explain a lot of things because of evolution. Of course, that is there. But again, I come back to why do we have to care about that? Anyway, it is happening, right? But what is the current use of knowing about evolution? Let us take up COVID, which we are all aware of, which happened a few years ago. So during the pandemic, the virus, we have learned that it was COVID-19 virus and the people were developing vaccines for the virus, right? And the knowledge of how virus is evolving very quickly is useful for us to develop vaccines. right?

When I say how quickly it is changing, that means that the virus, the protein coat of the virus is rapidly changing, rapidly evolving according to the current environment. So that knowledge, that evolutionary, from an evolutionary sense, it is important to understand vaccine development. Let us say we want to develop new crops, new agricultural crops or new hybrids. What kind of traits to select in order to develop new crops, whether rice has to be grown in a say drought prone area or whether it has to be grown where it is extremely arid or extremely salty kind of a marshy area. What are the traits? What are the traits which allow rice plant to kind of overcome, to adapt to these situations are important.

And that is again, an evolutionary understanding will help us to make hybrids and to make, to develop new crop varieties. Let us think about conserving animals, conserving plants and animals, big or small. You know from biogeography, whatever I talked about in a few minutes ago, you know that there are various plants and animals are distributed in various areas right?. Some are spread widely, but some plants and animals are endemic or restricted to certain regions only. And these animals and plants might face risk of extinction and may face other land use changes or other environmental changes, which are including climate change.

So, there might be overall loss of certain endemic species or in general, there is loss of biodiversity over in present day and age because of various factors. So, to understand what are the, how to conserve these endemic species, we need to understand, okay, where are they coming from? Why are they endemic? So, and again, an evolutionary or a biogeographical knowledge is needed for these kinds of applications. So, evolution is not just to know that, okay, it is there in textbook and it is there in the biology syllabus and that is why we have to study it, but it has immediate implications to whatever we do in our daily lives. okay So, I am listing out some popular books to read here to know more about evolution.

These are, again, you do not have to read very formal textbooks. There are fantastically written popular science books with which anybody can read and understand. And these are some of the ones which are well written books, which you can buy it in a store or some things, some of these books are also available online. So, in the next lecture, we are going to be continuing on detail about natural selection and other ways, other mechanism in which evolution happens, that is your genetic drift, gene flow and mutation. Thank you.