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W8L39_Species, Speciation and Biodiversity - I

Hi, my name is Jayanti Mukherjee and I teach at Azim Premji University. So for today's this week which is the 8th week of our NPTEL course in I Think Biology, I am going to talk about species, speciation and biodiversity very broadly. So let us see some of the learning outcomes of this whole week. We are of course going to recap some concepts in evolution and as you might have learned from Dr. Divya, she was talking about evolution, we are going to touch upon some of those topics here. We would like to understand what are species and how they came into being like for example, how did speciation happen in nature, how are these species distributed in nature.

For example, what is the biogeographical pattern of species distribution, what do we understand by biodiversity?, is it only species diversity or is it something else? and how do we actually measure biodiversity? So these are some of the important topics that we are going to cover in this lecture. So let us proceed. First, we will proceed with two concepts in evolution that you have already studied.

The first is microevolution. What do we understand by microevolution? So microevolution is actually the events occurring within the species or population as I have given here. So from this figure, say for example, you can see the species happening within a population. Take that example of this you know bird sitting on this tree. Let me put my pointer out and you can see that this bird is actually feeding on the green ones whereas the dark or brown beetles are not being fed by the birds.

So this is the simple example which is actually very similar to the industrial melanism example that you have studied and it says that the bird is selecting those green beetles for feeding whereas these brown ones are left out in this environment. So it is quite natural that in this environment, the brown ones will be more successful in surviving as well as reproducing to the future generation. So this is a pattern of speciation and this is microevolution. So how nature is, the selection pressure nature is imposing, how it is selecting the brown beetles and how they are evolving in that particular environment. So if you recall the previous lectures, you will see these kind of mechanisms actually happen through mutation.

It can happen through migration. Some species move into a new area and it can happen like that. It can happen through some genetic drift which is a random disastrous event it can happen and underlying all these things is of course Darwin's proposed theory of natural selection. right? so it’s occurs. So it's the underlying mechanism for all these mechanisms. And above this microevolution is something called the macroevolution.

So what is macroevolution? The events or levels above the species. So this is what we mean by macroevolution. So one part in micro species are evolving in their own way within their own environment. But when we zoom out and we actually interlink those species, so if we find similarities in different species of different clades or sections and we come up with a picture like this. So here you can see we have three kind of as we all know already we have three kind of kingdoms, bacteria, archaea and eukaryota.

So when we zoom out, this is the picture that we get because of the interlinks between these organisms and that is what gives us a picture of how evolution has happened over millions of years. So this is macroevolution at a larger scale and these are done through what we know as a mechanism as speciation. So micro happening at a smaller scale, macro happening at a larger scale, but the bridge between these macro and micro is species. So species form the bridge between these two. So what are species anyway? So this is in Latin term, Latin as we know it is means the kind and as you know this picture is very familiar to you Charles Darwin who is the father of evolution and proposed the theory of natural selection.

So as we know he went to this HMS on HMS Beagle to his voyage to Galapagos where he collected many different species or many different organismic kind which he identified meticulously documented and then he started them to come up with this theory. right So even he was perplexed by what species actually are and he said that it is really laughable to see what different kinds of ideas are prominent in various naturalists mind when they speak of species. So it all comes I believe from trying to define the indefinable. So he also agreed that here we are trying to define something which is indefinable, right? Because there are a lot of confusion in this realm of study, in evolution has been as ecology about species, what actually a species is. So in this now a few slides ahead we are going to talk about some of these confusions or controversies related to species.

So before doing that we know species is what we are going to talk about here, but let us take a glance on what are above species. So you probably already know and know this chart or this nice hierarchy of life and domain and what we call as you know kids prefer cheese over fried green spinach. Kingdom, phylum, class, order, family, genus, species. So this is how we used to remember in our childhood. So this is what the hierarchy is and just taking an example, phylum, family, genus and species are the few different things that we mostly emphasize on.

We generally go into order or class sections, but these are the more important things that we emphasize on to classify when we do some study or research, right? Here is an example of red wolf. As you can see, vulpes, vulpes is the species. So vulpes, vulpes is the genus and vulpes is also the species. Lot of species have this kind of similar names. So it is very similar to for example, I am called Jayanti Ray Mukherjee or Jayanti Mukherjee.

So Mukherjee of course is my now becoming genus name whereas my species is Jayanti because I am specified by only Jayanti, right? Mukherjee is becoming my family name. So something of this very similar idea is also applied here. And this belongs to foxes, belongs to the family canidae, order carnivora which feeds on flesh, class mammalian, they have hairs on their body and phylum Chordata, they have a vertebrae and of course kingdom animalia and Eukaryota which has, they have very hard down nuclei and cell organelles, right? So this is an overview of what are above species and most of us are studying biology actually knows about more or less this kind of things. However, when we go below species, it becomes a little bit blurred there. So here is some existing concepts that I have highlighted.

One is varieties. Varieties are commonly used term for variation within a species, right? It could be due to polymorphism, we will talk about it. Polymorphism or environmental changes for example, if something occurs in particular environment and it gets some specific trait from that environment, it is actually called as a variety, it can be called as a variety. Now why I have separated variety and all the others here is because variety is more of a colloquial term. So it is naturally, normally while we won't use it in, do use it in scientific literature, but in scientific literature we more use a concepts like subspecies or ecotypes. Accession and cultivar are these two terms which are more used in agriculture system where when some plant breeder or plant biologist go collect one particular population from a particular area, they name it according to that number where they have collected from so that for future reference, whoever is studying that kind of an ecotype can go and get it from that region.

So they have particular names or numbers for these accessions and cultivars, right? Cultivar is again a very technical term when you select for cultivar is more associated with artificial selection, not natural selection, okay. So these are some technical terms, I just thought I will bring it up here, but you do not need to go into too much details of this. Now we are talking about, let us take a look at, we were talking about this confusion existing on what are species and what are not and we will talk about this with the tail of two crows, okay. So Carl Linnaeus declared Carrion crow and Hooded crow as separate species. We all know these crows, we have seen their pictures, we just know what they are called.

So this is common raven which is also called as a Carrion crow. You can see Carvus corax, whereas this is a hooded crow, it is a gray color crow and it is called Carvus, it is a separate species, same genus, Carvus cornix, okay. So for ease purpose, I am just going to refer to this one as a black crow and the other one as a gray crow for now. And let us see what I am going to emphasize on. So when scientists started looking into the genome of these two crows, they found that only a very small part, you can see 0.28% of their genome differs between these populations. So it is almost same species, but not same species. So this section is, this section of the genome is located on the chromosome 18 in an area associated with pigmentation, visual perception and hormonal regulation. So you can see how very minute section of the genome if it is differing, even then it can become a separate species. People can call it a separate species, but actually is it a separate species, right.

So to take it further, here is this black crow, here is the gray crow, you can see the black crow is much, much widely distributed in nature and the gray crow is only restricted in this part of the Europe and leading towards little bit of Russian part also. So we will concentrate on this population here in the Europe and you can see the middle map where there is a fine line drawn, a white dotted and white bold line, which says there is a demarcation between, so the right hand side is more predominantly found gray crow, whereas in the left hand part of that line, it's more predominantly of the red, sorry, black crow or the common raven, right. But what, why is that line drawn? This is why. Because along that line and adjoining areas, Corvus cornix corone, okay, you can see subspecies corone, this is a hybridization zone. So in this zone, the species can also hybridize, okay.

Why is this important? We will talk about that in a bit. Earlier we had an idea that if it is a different species, then it won't be hybridizing with or breeding with each other. But here this crow is breeding and producing a mix, which is a subspecies we have named Corvus cornix corone. So as you can see, it's not only one type of hybrid, there are, there can be multiple different types of hybrid occurring in nature, whereas these two crows are separated when they come together, they can still hybridize and produce successful offspring, right. So then again, it confuses us what is a species?, what are species actually?, right.

Similar types of examples you will always also see in plant kingdom. For example, this is a Gray oak on the left you can see, whereas this is a Gamble’s oak. The main difference is in the leaf, how it is and of course, a little bit of difference in the fruiting pattern, but you can see the leaf is significantly different. Here the leaf is very simple and small, here the leaf is so much serrated and much bigger. Below you can see the distribution maps of these two.

So how they both are, so gray oak is much scatteredly distributed in the area, whereas gambles oak is also found in that area but much more abundant, okay. But then if it is a different species, do they hybridize or not? Well, yes, scientists have also found that they also hybridize and the hybrids are actually in the middle, their leaves are actually in the middle of the gray oak and the gambles oak. So it's less serrated than gambles oak but more serrated than gray oak. So they are forming fertile hybrids.

So again the confusion persists. So what are species? What are we defining actually as species, right? So this brings to our three different concepts of species that we are going to emphasize or highlight in this part of the lecture which are morphological species concept, biological species concept and phylogenetic or evolutionary species concept.

Let us see what these things are. Morphological species concept. So here, needless to say, the name suggests that groups of individuals that are morphologically similar or morphologically distinct from the other such groups, okay. You don't need to read the whole slide here, just concentrate on the morphological species concept.

So appearance is everything what it means. So if I am a human, I definitely look different than a dog and hence we are different species, okay. But confusion, can confusion occur in this that I am different from dog? No, but confusion can occur in something else, okay. Morphology can be confusing, different looking organisms are not always that different, okay. So for example, this is a day meat egg fly and the male and the female looks very, very different, right.

So when you are a scientist, say you have a concept in mind, I am going to classify these species morphologically based on this morphology, how are you going to demarcate these things? They look very different. I am quite likely to say that this is one separate fly species and this is a, sorry, this is a butterfly species and this is a different butterfly species, right. So this is the major confusion in the morphological species concept. So then we take it further and this was one of the primitive species concept that was existing. When scientists took it much further, they relied more on the biological species concept, right.

So groups of individuals actually or potentially interbreeding natural populations in natural populations reproductively isolated from such groups. So what do we mean by that? This is also we were emphasizing in our previous examples when we took about this crow and the Grey oak, right. Ernst Mayr 1942 was the first one to actually define these as potentially or actually or potentially interbreeding. So when it comes potentially that is the reason I have highlighted it, then there is in a Grey zone. That is why this confusion arises, what is potentially interbreeding natural population? So for example, if you take that example of the crow, two crows, they were separate species where the Raven is in different part, the Grey's crow is in a different part, they look pretty different from each other, but when they are coming together, they are still potentially interbreeding.

So should we call them separate species? What do you think? Right. So this is biological species concept, but of course, this grey zone is when they breed what will happen. Biggest example in nature, Homo sapiens, Homo Neanderthalensis. So it is scientists have studied now that sapiens, us humans, we also interbreed with the Neanderthalensis like there is genetic evidence that suggests that these two species interbreed, then why are we calling them separate species? What is the confusion here? So now what kind of species are we arguing about? Is it morphological, biological or evolutionary? So these are something doubtful definitions that we need to keep in mind when we delve into the literature of what are species. So let us take an example of biological species concept now that here you can see I have suggested appearance is not everything.

So similar looking individuals may not be compatible for mating due to other reasons. So keep in mind the crow example that we took that was just the opposite. different looking individuals although not very different, but still little bit different looking individuals were actually mating to have fertile offspring, but here is just the opposite. Similar looking individuals, these two bird species are very similar looking, but there is something that is stopping them from interbreeding or mating in the areas where they are coming together. So this concept is not according to the similarity of appearance.

Appearances helps to identify species, but is not everything to define a species. So what actually happens, we will take a look. So western meadowlark and eastern meadowlark, you can see the scientific name we have written here. These two species occur in a very overlapping zone. You can see western meadowlark is very predominant in most of the southern part of the United States, whereas eastern meadowlark is going to the eastern part of the United States, southern eastern as well as going to Central America and parts of northern, very northern tips of South America.

But what happens, so this is very overlapping zone, very, very overlapping zone for both the species, but what happens actually why they are not breeding? Why were we calling them? They are looking similar also, but they are not breeding. What is actually happening there? So when scientists actually examined this, they found that even though these two species have very similar looks, they have actually a very different call. So in birds, if you remember, you might have seen birds around you and you might have done some bird watching also, you see that calls are very significant for these creatures, right. They identify each other, communicate with each other with these calls. And if they are, say for example, in a breeding season or a mating season, if they are actually looking for a partner and the call they are looking for is not familiar, then they do not go for mating, right?

So that kind of actually starts to make a difference or an isolation between these two populations. So when we mean isolation, it is actually not only geographic isolation, it is the reproductive isolation. So even within that same area, although we will also talk about this case study in our next section of the lecture which is speciation, but here let us think about it in the same area, same looking species, two bird species, we are calling them different because they are not breeding because of some behavioral changes which is their call when they are either in the breeding season or different types of call and not recognizing the call of each other, okay, which is causing a reproductive isolation between these two. Confusion comes when species or groups actually are potentially reproducing. As we said, you know, these example we said, I said in my previous slides, these are male and female and you can see this ant species.

One big ant or the queen whereas these small ones, black ones are workers. So these are different types of variation that may exist in the population what we call as the polymorphisms. So this is sexual dimorphism and this is functional dimorphism, right. So this is male and female, they look separate. This is the worker and the queen or drone and the queen, whatever, they are functionally different so they look different.

Now if I am a naturalist, I have no idea or if I am a nature lover, I am going to nature to look for organisms and I find these two ants, definitely I will think that they belong to two different species, right. I will make the mistake. But when you actually go and follow them, go into their nest and actually see that they are living in the same nest, then you realize, oh, these probably are not same, different species, right. This is how the story builds up. Here you can see humans, female humans, we have some pictures here.

They look so very different. It's very easy to confuse them, but the variations may exist within species also due to geographic variation. They are coming from cold climate, coming from hot climate, different physiologic, different anatomy also, morphology, sorry, appears in these organisms, right. So biological species concept, then summing up, it is the very oldest species concept and the most widely used. Some issues are there. Many species that seem to be very distinct turned out to be hybridizing successfully like the crows and the gamble oaks.

When it comes to biological species concept, we are mostly talking about sexual organisms which can interbreed or not. What about asexual organisms, bacteria? How do we study speciation in them? What is the species in those kind of organisms, right? Then we come to species separated. We were saying that they are species isolated. So when they are isolated by a mountain or a river or a glacier, when they come back, will they reproduce or not? That is a big question, right? When you bring these things back, whether they will reproduce or not.

So all these things are some issues. Now how can we solve some of these issues? How about looking at the history of the population to decide whether it is a species or not? okay That is one of the main things that next step of it. So some take homes from biological speciation. These are any biological differences reducing the gene exchange or causing reproductive isolation. They need not be 100% geographically separated. They can be otherwise behaviorally or functionally separated and useful for distinguishing species reproducing sexually. They cannot be used for you know asexual breeding mechanism. So that is a limitation here. So how to take it forward? Taking it forward would be the evolutionary species concept or phylogenetic species concept. So I have put the definitions here. You can pause the video and look at the definition. but basic thing is that a species is a smallest monophyletic group or clade of common ancestry, right? Very similar looking species.

What do we mean by that? I will come in a bit here. So if you see this diagram, this is a clade when we call one clade, it is a group, right? This is a clade. Here one group has separated into Drosophila dentissima, Drosophila melanogaster. So this is one speciation event that has occurred which has given rise to two different traits or sets of traits which has diverged. These sets of traits will be more clearer if you go and look into the evolutionary history or genetic structure and variation of the species. A species at the tip of the phylogeny, it is speciation occurs when a population undergoes fixation of genetic differences.

What does it mean by fixation? Fixation is nothing but when a trait actually getting fixed, a trait getting fixed means in a heterozygous condition which is say for big A, small a you know two alleles are there in a heterozygous condition, it occurs 50-50% in a population. So big A will be found 50% of the time, small a will be found 50% of the time. So it is fixed. If not, we can always say the population is biased towards big A or small a, so it can go anywhere.

If it is still not, the trait is not fixed. right? Then it can be identified using unique sets of traits that a group of population share, but may not be found in other close-related populations. So now since we are not talking about only the biology or morphology of a species, here we are concentrating or saying a unique sets of traits. So it is not that evolutionary species concept or phylogenetic species concept, do not take a morphology or biology into account. So this is, they do take morphology and biology into account, but this is in addition to that they also look at genetic traits that are aligned with these organisms. okay So it is some extra work and we could do it because of this extra work, we could do it because the genetic tools, molecular tools are nowadays available during handling and it makes it easier for us to test these things.

So my question for you to think would be in which kind of species would a scientist want to employ the phylogenetic or evolutionary species concept, do you think? Take a bit, take pause this video and just think about it. yeah Probably you have thought it right and those are organisms. For example, if you think about this question again, for example, if I am a human and there is a dog, there is no confusion between us being a different species. But if I am a Homo sapiens and if there is another Homo Neanderthalensis in this room, then the confusion arise and they are also interbreeding, right? So what then makes a species? So in those kind of more or less confusing situation, it makes more sense to go for the evolutionary species concept or phylogenetically test these things to see whether they are same species or different species, right? So we will take a fantastic example of giraffe, African giraffe.

It is called the scientific name is Giraffa camelopardalis. And it is actually, this was a study done by David Brown and Rick Brenneman. So David Brown is studies, he is from this zoo in Omaha, Nebraska in the US and they both were started studying the giraffes in the zoo and their interest, this variation in these animals actually caught their eyes and they started studying them in a more critical way. What caught their eyes was something like this, if you see this picture. So all these animals can be present in the zoo, which is Omaha zoo or something a big zoo, they will have lots of giraffes from lots of different countries. So in the zoo, they had these giraffes from all over the world and what they started noticing was very distinct stripes within these animals.

So these stripes are kind of very distinct, so that caught their eye. So now question of course came to their mind what we will ask with are they same species? Of course, we know that they are African giraffe and we have named them Giraffa camelopardalis, right? They are same species. So why is the confusion coming? So just before going into that, based on phylogenetic history, African giraffe is, so this genus Giraffa and Okapia are belonging to the same, they are very closely related and Okapia as you see I have put a picture here, very nice beautiful animal, but this species only or this genus only is found nowhere else in the world other than the Republic of Congo, only in this area. Whereas giraffe, you can see the distribution of giraffe is all with these colors are highlighted in this map here and we will get into how many species or subspecies are there. So David Brown and his colleagues were starting to analyze them and they collected tissue samples from almost 266 giraffes and 1707 nucleotides from DNA of each of these animals. Their common ancestor is almost 1 million years ago and they came up with, here it is like 5 lineages highlighted, but they came up with 6 different unique lineages.

Here this map actually emphasizes that. So you can see the patterns as we saw in the previous figure, the patterns are very, very different from each other, right? So this is distinctly from West Africa. This is the Rothschild's giraffe, it is very beautiful striped Rothschild's and reticulated are one of my favorite and you have then here South African pattern and Angolan pattern, which are kind of very similar also. In a look way, so the stripes, you can see this is a merging pattern, right? So in these two clades or these two separations, but the pattern is morphologically looking the same, but they belong from two different areas. So whole question of what we learned before, if technically if you bring these two giraffes together, they will definitely be still able to, my hypothesis will be, they will be able to meet. Whereas now the question comes, if I bring together West African giraffe with Rothschild's giraffe or South African giraffe, will they be able to meet or not? That takes us to our biological species definition, whether it will produce successful or fertile offspring, right? This is, I just put this slide because this is another way of representing it.

So you can just see how they are distributed. but these are the different types of giraffe. This is Rothschild's giraffe, reticulated giraffe, South Savannah giraffe, very different again. West African giraffe is quite different than reticulated, Rothschild's, Nubian giraffe and the Kordofan giraffe. So the Wikipedia page that I have cited here actually has all the details and you can go and read about it from that too.

So all the details of their study they did. Now after, so this study was done in a bit early, but the latest study that came up in 2016, this published paper in the journal Nature, now they say that DNA reveals that giraffe are four species, not one. Very interesting, right? Till now we were actually seeing giraffe are camelopardalis, there was only one species, rest all there were considered as subspecies, right? But now in 2016, they have declared that it cannot be considered same species anymore because currently these four species of giraffe which are recognized as separate species do not interbreed anymore. So geographically being isolated from each other for so long, they have now also started to be behaviorally, to be genetically so much different from each other that when they are coming together, they are not anymore recognizing each other, they are not compatible sexually also with each other. So this is a significant example in recent years how these species identification actually work. So now of course the question in your mind should come that what does it mean by genetic differentiation? So how much of genetic distance is valid for a species to be a separate species, right? Is there a threshold for that? These are the questions that you should be now asking yourself.

So with this we come to the end of the concepts and this section of the lecture. So here we studied what are species, how they are defined, what is the crypticness of the species, what are the controversies related to that in a definition of species. We talked three different species concept morphological, but here we highlighted more on biological species concept when two species are not breeding with each other it makes them biologically a separate species and evolutionary species concept where these two genetic distance is formed between due to the isolation, reproductive isolation where even if they are very closely looking or similar looking they are not breeding because of the genetic distance that has been related within them. So phylogenetic species concept makes more, becomes very important when we are actually testing very closely related species to reduce or you know reduce that confusion that we have about definition of species. So with this I have, we will address there is an existing misconception in evolution. Is evolution always perfect? right? What do you think? Is evolution always perfect? So best suited to a particular environment.

We always say that evolution it makes phenotype that is best suited for a particular environment. So don't confuse that evolution is always perfect. When it is very partially true statement, it is always true that perfection or best suited it becomes only when the environment is clear, right. When the environment connection you can be. One organism which is best suited in India if you take that organism to the US it may or may not be best suited in that environment, right? It may die. So how is it suited to that environment it makes more sense. So the question, my question to you to think would be how do we know that the pattern of giraffe is perfect in that environment or not? So think about it. And another question I want you to think these two questions for our next section when we talk about speciation is how long do you think the speciation events take place to or takes to happen and what are the different conditions the speciation can depend on, right. With that we will come to the end of this section and thank you for listening to this lecture and I will see you in the next lecture.