Course Name: I Think Biology

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W8L42_Speciation

Hi, welcome back. My name is Jayanti Mukherjee and in this week where we are talking about species, speciation and biodiversity. This lecture we are going to focus more on speciation. If you remember our last lecture where we actually spoke about what are species, what comprises a species, we talked about biological species concept, phylogenetic species concept and what are the differences like why some researchers have chosen to use biological species concept, when does phylogenetic species concept become more important.

In this lecture, now we are going to talk about speciation. So, how does two species split or one species split into two in nature, right? That is the process of speciation.

So, let's see how that happens. So, if you remember I had given you two questions from last class. How long do you think speciation even take to happen? So, if you remember we had shown you a lineage or a clade grouping. So, from that you can always say, I am sure you already know and you can say that speciation will depend or time of speciation will depend on the time of generation time of the species, right? A favorable gene can be fixed faster in a population which has smaller generation type.

Say, bacteria multiplies in 20 minutes. So, in bacteria that favorable gene will be fixed much faster. So, speciation will happen, sorry, can happen much faster whereas in others like humans or elephants it will take much much longer time to happen. What are the conditions that it depends on? This will also depend on the environment that they are in. So, how strong the selection pressure of the environment is that will actually help that species to split, right? And those are the things that we are going to delve into in this lecture.

So, let's get started. A brief outline is speciation. We are going to talk about different ways a species can split and in the second unit we are going to talk about how do speciation events look like. So, for example, if you zoom out speciation is happening, right? But when it is actually

happening you are not able to see, you are not able to evidence speciation very easily. But when you zoom out through a macro scale and how can you see these speciation events have happened from millions of years through phylogenetic trees we will see some of those events.

Through two case studies one is using Dipterocarps, you will know all about it when we talk about it and the second case study is on felines which we have actually taken from iThink biology book which you can go and read about it there. So, let's get started with speciation. Speciation is nothing but a lineage splitting event that produces two or more separate species, okay. So, now how does it happen? You might have already seen in this kind of an image you are aware of, right? So, there is a banana, there are few flies on the banana you can see and suddenly some environmental catastrophe happens or something happens, there is a water body which is flowing now from that island. You you you can see these trees are separated and these banana peel is separated.

Now, when this barrier comes some of the species depending on their size are able to cross the barrier. So, gene flow can keep on happening, but some species which cannot cross this barrier physical barrier, geographic barrier will separate or will evolve into having different characteristics which when brought together will not able to breed or interbreed again. So, that is the simplest form. There is a species, there is a barrier coming in and it is now splitting into two species. Now, very important point here to think about is what kind of barrier are we talking about? Okay.

So, if does it mean that if there are big population of elephant in a place and I put a hill in between or I put a very big wall in between and the elephants are seriously really not able to cross this wall, human made wall, will these two species evolve in different into different species? Okay. So, this is the question we need to ask and think, right. What kind of barrier? So, barrier actually definitely it is a geographic barrier here we are seeing, but actual barrier is in the form of reproductive barrier or reproductive isolation, right, which something that causes the males of one population and the females of one population to be not able to compact, to be not compatible anymore. Okay? So, let us see how some of these processes can happen. So, bringing in the biological species concept once again, if you remember there was reproductive isolation via barriers and which was not enabling these two species or two lineages, groups to meet.

And here you can see lineages within the original species exchange of gene is happening over time, there there, these two lineages are splitting into two. The original species diverges into two groups, a barrier to reproduction emerges. So, it is impossible to distinguish morphologically. Morphologically it looks very much the same, but ecologically, behaviorally it is so much different now. And of course, we will talk about some of the reasons why it can be different that it has a reproductive isolation evolving within that population which forbids them to interbreed.

So, going forward there are two broader classes, you have learned this in school and it's I'm sure very much known to you, two broader classes of speciation, one is allopatric and the other is sympatric. Allos comes from the name another place or Patra Homeland, whereas Sym it is when something is together at the same place, it is called sympatric. So, as you can see, I have given geographic barrier versus biological barrier, this is because allopatric is another place, right. So, geographic barrier or physical barrier becomes more important in this case, but this can physical barrier ultimately will eventually lead to a geographical, sorry, a biological or reproductive barrier. Whereas in sympatric speciation which is together two lineages are in the same area, there the biological barrier becomes more important.

So, reproductive isolation happens within the same area okay. So, now how does this happen? Allopatric, if you remember we had talked about western meadowlark and the eastern meadowlark and we are talking about speciation. This can be taken as the case of allopatric speciation. Original population was separated during the ice age. So, very much it was partitioned during the ice age, there was ice in between, so those two population could not communicate and could not meet.

After ice age or ice melted and this population again came together in certain parts of United States, it was seen that they even though these two meadowlarks look very much very, very similar, they had developed some behavior symptoms through mating calls, right. Through mating calls they had mates come up with some behavioral symptoms where one population males were unable to mate with the females of the other population which actually led to. So, the species were different now, genetically it has separated so much that they were not able to interbreed anymore. This is the example, very good example actually of allopatric speciation and allopatric speciation is one of the most frequent or happening speciation that we see. Why? We will talk about it also later.

So, here the two species are distinct now. Whereas sympatric is the same area as you saw, sym or same area, original population, some polymorphism within the population either can mutate, right, some mutation can happen and a polymorphism within a population can evolve or there could be so much variation in the population that one sub-section becomes little bit isolated or isolated in the sense it can be say selected for increased fitness in some subtype of the habitat. Now, what do I mean by that? If you can see this you know figure or picture, this shows lot of ecoregions, some scientists have classified different ecoregions of the world. So, if you see within an area or within India if you see or within this small area of Africa, there are lots and lots of different ecoregions clustered within the same rich area. So, if a polymorphism within a population happens and that polymorphic population, that that variation becomes suitable to a very small sub-section of that habitat or ecoregion, it can actually evolve character characteristics that will be highly beneficial in that sub-section and give the species an increased fitness.

And so much increased fitness that it becomes very successful in that particular ecoregion or sub-section of the habitat. This could eventually lead to speciation, there are have been studies with that shows speciation have happened like this many ways. But what are the different ways that it could happen? We are going to talk a little bit more examples of it now. There are other two speciation, allopatric leading to sympatric, but in between you can see we have included peripatry and parapatry. Let us see what are these.

So, original population all are same. I am not going to again talk about these two, but now you see peripatry is something where a new niche has entered. So, for example, what they are the arrow says a sub-section of the population or sub-population is actually going out of that place and establishing in a new region where after isolation for many years it is now becoming this yellow color. So, it is losing the essence of its green or the characteristic it had and evolving into the new genes or new set of variation. So, that can lead to speciation and this type of speciation, it's actually a type of allopatric speciation and it is known as peripatric speciation.

In parapatric speciation what happens, a new niche can enter, but now it is a little bit different than what we talked about the peripatry. What happens is there the population is like this and it increases. So, the population is greater now, but say it also starts to occupy a habitat which is different than the other. For example, like this, say this big bubble is in a habitat which is red whereas the small bubble now extends into a habitat which is more blue. So, when it is entering that new habitat it brings in some new mutations or some new characteristics more suitable because eventually the species's goal is to have increased fitness, right.

So, increased fitness when it is acclimatized into that new region increased fitness gives rise to new traits and eventually over the years what happens that it has been seen that these two species are again or these two lineages I should say are again not able to interbreed and hence lead to two different species, okay. So, this is a very broad way of say these two species. We will now go to a few more examples of these. So, just to sum up these geographical variation or geographical barrier leading to biological barrier giving rise to which is called allopatric speciation whereas sympatric speciation. Now, we will get into these three different types where it can happen which is one is premating, post mating pre-zygotic and post-zygotic.

So, through three different phases, one is before even reproduction how barrier is coming reproductive isolation is happening, one is after reproduction happen but zygote is not able to form. So, pre-zygotic post mating, barrier can happen. Third post-zygotic okay, fertilization happens, zygote is formed, 2N happen, everything happen but why then it is not becoming into a new individual or fertile individual. So, where is the barrier reproductive barrier there? Let's take some examples.

Isolation before reproduction, pre mating, okay. It can happen temporally, ecologically, behaviorally and mechanically. Let's see some examples. So, people have actually shown that this kind of speciation happens in nature and examples have been recorded through experiments as well as observations. Okay, as I was saying, temporal and seasonal is the first one and I have written here cricket species.

So, let's see what can happen. Studies have shown that examples of very closely related cricket species have been found. They maybe look a little bit morphologically dissimilar but also in the same area they can occur, but two closely related species, one reach reproductive age in the fall whereas the other reach reproductive maturity in the screen. So, obviously, these two species cannot mate with each other. So, that has led to different speciation in the same area.

Okay, Ecological or habitat. A very good example, in this actually comes from Japanese beetles where two species of Japanese beetles have been shown to be feeding on, very nearby, but feeding on two different plant species. Okay, and these finds mate in those plant species. Eventually what has happened that it has shown that if you cross breed them somehow whatever plant species they are feeding on they don't like the females of the other population which are feeding on a different plant species. It's very interesting, isn't it? How this micro-habitat or even feeding on a particular type of diet has led to separation in a beetle species. This has also been shown in Drosophila like organisms also.

So, this is one kind of ecological or habitat preference separation which can lead to two species. Third is the Behavioral or sexual which is a very, you know, lot of wildlife videos you might have seen. They talk about sexual selection and sexual, you know, preferences of birds, insects, frog calls. These are the very good examples of how behavioral or sexual calls, mating calls can lead to different kinds of species where if they don't recognize these calls, they don't actually mate with each other.

The last one, mechanical isolation. This actually have been shown in some plants and its pollinators where different plant species very similar or in particular area very similar plant species, but they have preferences for two different pollinators which has eventually led to different shapes of the floral structure and eventually led to significant reproductive isolation leading to speciation, okay. So, two were in the same habitat, had preference for different pollinators and started fixing genetic traits with that particular pollinator. If you delve into this literature, you will also see it's something called floral constancy, okay. So, plants with specific pollinators have led into, can lead into speciation in many cases and it has been shown in nature. So, here are the some examples of how pre-mating isolation or reproductive isolation can cause sympatric speciation.

Now, let's go to some post mating and pre-zygotic examples. Isolation after reproduction, but

before the formation of zygote, okay. First, I have written Conspecific sperm precedence and second is Gametic isolation, but here I have given another example that incompatibility of sexual organs can also happen like in some drosophila species, some other species also they have shown that the genitalia, male genitalia and the female genitalia often say if they are acting as a lock and key system, in some species that lock and key if it is modified, say for example, some kind of mutation or evolution has happened and those genitalia don't match each other. So, then the organisms become incompatible leading to different species, okay. Conspecific sperm precedence, what does it mean? In ground crickets, they have shown that the females actually mate with a lot of males hetero specific, right.

Same species, different species it mates with a lot of males, but eventually fertilization that is happening to give rise to the zygote, okay that is happening only with conspecific or same species sperm, okay. So, their body, they are physically they are mating with different species, but they are physiologically their body is rejecting the sperm of any other hetero specific males from any hetero specific males. So, this can, this type of sperm precedence or sperm competition you can say can lead into speciation. Gametic isolation, a lot of marine invertebrates they have shown that cell surface protein, so if the male and females come together there is a mismatch or misrecognition of the self surface proteins and that is the reason these two cannot mate and hence the gametic isolation happens which leads to speciation. So, even though they can mate, there won't be because of this not recognizing each other the successful zygote won't be formed, okay.

So, that can lead to lack of interbreeding or lack of breeding between these two lineages and hence leading to speciation. Let's go to the next one which is post zygotic or the last one, post zygotic isolation. Isolation after mating and this is when I talk about the examples you will know that you have already heard about a lot of these things, okay. Hybrid inviability, there could be some missing genes in the hybrid, okay. So, it is either sterile or the hybrid forms, but the embryo is not able to survive.

So, that is the reason there could be lack of actual establishment of the zygote. So, zygote is formed, but after zygote formation the establishment is lacking. Hybrid sterility, it is, hybrid is formed, it is zygote is also formed, but those can happen like mules, liger, tigon all these examples comes in hybrid sterility. So, mules are sterile, right, but the organism that particular organism is surviving. It is not that particular individual is surviving, it is not that they are dying, but they won't be able to reproduce.

So, eventually it ends there, right. So, hybrid sterility. Then another last one is hybrid breakdown. So, here there is a famous Haldane's rule which talks about this. I am not going into the details of that, you can, it is beyond the scope of this course, but you can go and look it up where it says that hybrid breakdown happens. So, for example, F1 could be fertile whereas in F2 it becomes inviolable or sterile, okay.

So, F1 generation can happen, but from next generation it becomes sterile. So, that also could lead to a break in this reproductive or reproductive barrier which could lead to two different species not able to come together to mate and produce successful offspring, okay. So, now these are the broader categories of how we we saw how allopatric as well as sympatric speciation happens. Now, what is happening at parapatric or, you know, peripatric speciation? Before going to that, Dobzhansky-Muller incompatibility is something that happens in these kind of reproductive isolation. This is being taken, I have taken this from Wikipedia, so you can of course go and read about it and there more.

This just suggests that the wrong combination of allele, okay, it can lead to functional mismatch. So, for example, if there is an ancestral population AA, Big A, Big A and Big B, Big B, this can eventually separate in two different areas and one of them can lead to some different new mutation and new mutation can get fixed, okay. Whereas, eventually when they come into contact again, there's recognition or mismatch might happen where A and B does not recognize each other. So, more detail can be found in, you can read in Wikipedia, but this is some of the underlying reasons or causes behind these hybrid in incompatibility that has led to sympatric speciation, okay or that can actually maintains species identity in the same area.

Now, let's talk about Peripatric speciation. This is also called founder effect, a special type of allopatric speciation. We already saw previously where a small population with rare alleles that is very important can survive or establishes in new territories and have an increased fitness, okay. So, this is just a diagrammatic view. Here this small heterogenic population have separated, but you can see after many generation it can become red or blue, it is like this. So, parent population, this is heterozygous, it has migrated, population after couple of generation you can see the red is decreasing and it can eventually lead to with no red at all.

So, the founder population has established in a new region, but now it has lost some of its genes, whereas separated and to another population or another species, okay. So, this is called peripatric speciation, not very common, more or less common, but not that common as other allopatric speciation. Peripatric speciation is even rarer, there is no physical barrier or gene flow here. Say for example, it studies like this have shown in this species of Anthoxanthum odoratum, a grass, which you, if you remember the cartoon I drew, like I separated two different niches, one with red and one with blue. So, say for example, Anthoxanthum is extending its range, now it is going to an area where there is heavy metals present in the soil.

So, this grass has been shown to have evolved heavy metal tolerance in that area and actually separated from its previous lineage of species. So, speciation can happen like this with a good mutation or beneficial mutation, the grass has evolved to metal tolerance, which has led to a new species, okay. Or it can also be seen, it can also be seen in different temporal isolation, how

peripatric speciation happened that we saw in some crickets or it can be seen in some lizards also, where different time of the day or season is used for its activity or breeding, okay. So, now this this is overall most of the speciation that I have covered, but there is one particular very unique type of speciation that is not very much talked about, which is called polyploidy speciation, okay. So, what is polyploidy speciation? What is polyploidy? Whole genome duplication or doubling, not only doubling, so it can make multiple copies.

For example, in plants, you can even see not only diploid, you can see tetraploid, you can see triploids, you can see hexaploid, heptaploid, okay, octaploid, till then these many ploidy levels have been found in plants. And this particular species, I'm not sure if you're aware, this is Crocus sativus or the saffron, you know, the Jaffron spice that we eat in Biryani. This is actually a triploid, natural occurring triploid. So, what could be some of the benefits and misbenefits of these type of speciation? In early 1900s, actually researchers first observed this higher number of chromosome in plants and often it was associated with a, similar to something which is called peripatric, where in the same area species suddenly got a mutation or suddenly got some kind of environmental trigger where polyploidy started happening, okay. And researchers have shown that this polyploidy could give enhanced physiological function, increased cell size, increased cell surface area, which can lead to lot of benefits in terms of vigor and reproduction of that species, okay.

And these species have faster adaptability in a shorter period of time. So, this kind of species actually could happen very fast, okay. And that is the reason a lot of scientists or it confuses scientists because generally according to Darwin, we know that gradualism is the process of evolution, right, natural selection through gradual process. But when speciation becomes very fast, it is called saltation. There are events of saltation peaks where it can happen due to faster adaptability to the environment in a very shorter time.

And that could only happen through these kind of genetic anomaly, okay. But what could be the, you know, disadvantage of it? More vigorous, it has been shown these polyploids are very vigorous, more competitive, but on the other hand, they could be less stress tolerant. So, it is, could be very vigorous in that area, but when say a very bad stress or disturbance comes, they are not that efficient in tolerating that. Sometimes it has been shown. Other constraints or trade-offs could be, for example, this Crocus sativus or Jaffron, it is a triploid, okay.

So, if it is a triploid, then gamete formation and mating becomes difficult, right. So, there is a mismatch between them. Now it's a three chromosome, how it will mate with, you know, back to two or something like that. So, their genetic incompatibility also have been seen. So, those kind of cases, this becomes sterile and the plants actually sometimes takes off vegetative expansion or reproduction and it is not viable anymore sexually, okay.

So, a lot of these cases have been seen in plants more commonly. That's a very important way of speciation in plants. With this, I think I have covered most of it and I would be happy to answer your questions if you have any in the live section and I will see you again with the two very exciting case studies in my next session of speciation. Thank you.