

# **An Introduction to Evolutionary Biology**

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**Week 9 Lecture 41**

**What is a species?**

Hi, welcome to the ninth week of the course. So, one of the topics that it is originally written in the syllabus that we are supposed to cover this week is about phylogenetic trees. However, we have already covered it in Module 2, Lecture 3; therefore, if anybody has forgotten about it, I recommend that you go back to that lecture and revise. So, the main question that we are going to deal with in this particular discussion is I mean today and over the entire week, one of the biggest questions in biology is how new species are formed. But before we get there, we need to ask ourselves what we mean by the word species. And this is something that we have already looked at briefly earlier, I think in the second week or so.

But what we are going to do here is a much deeper discussion of the topic. Now, it turns out that this particular question, you know, the what What exactly constitutes a species is one of the oldest questions in all of human history and science. And this concept starts formally with Plato and Aristotle and has continuously evolved over the next 2,500 years. So, there is zero possibility that we will be able to cover that in this very basic, introductory course.

However, for those people who are interested in it, I can recommend this excellent book by J. S. Wilkins, one of the foremost authorities on this topic. It is called "Species: The Evolution of the Idea." Just in case you do not have access to this book, you can also look

at Wilkins's PhD thesis which actually later, you know, becomes this book above. That PhD thesis is available for free over here, and unlike many PhD theses, It is actually very nicely written in the sense that even for a non-technical audience, it is relatively easy to understand. So, the concept of species actually goes back quite a bit. The first person who tried to define it properly was the English biologist John Ray. And of course, it was used in a big way by Carolus Linnaeus, as we saw.

So, both of them, when they thought about species, meant what is known as the typological concept of a species. So, what exactly does that term mean, typological concept? So, what it means is that these people believed that, you know, any organism that you look at, Although you see a lot of variation in that, underlying that variation, there is an unchangeable type. And you know something fundamental, which is the essence or definition of a species. And all the variation that you saw is just some random noise around it. Now, if you look at modern taxonomy, which, of course, you know, has a lot to do with the way Carolus Linnaeus structured it, Even in modern taxonomy, this fundamental concept is still very much present.

And that is why, for example, when you look at a field guide or when you simply click a picture of something. Put it on an online database and ask, "What species is this?" All that field guide or that online database is doing is It is comparing whatever it sees with what it understands as the characteristic features of a species, and based on that. It is telling you that, okay, this is, let us say, the common crow, or that is, let us say, a dolphin, and so on and so forth. So, this way of looking at a species gives rise to what is known as the morphospecies concept. This is the first of the three species concepts that we are going to deal with.

And the proper way to think about it is A species is a community or a number of related communities whose distinctive morphological characters are. In the opinion of a competent systematist sufficiently definite to entitle it or them to a specific name. In other words, a species is whatever a taxonomist says is a distinguishable group. Now, obviously, there are some pros and cons to having this kind of definition. It is a very

practical definition, and it works for both sexual organisms as well as asexual organisms.

It works even if you do not have the living organism in your hands. If you have a museum specimen or a fossil, this is what has traditionally been followed. This is what Linnaeus was doing; this is what Darwin was thinking about when he was talking about a species. However, there are a few disadvantages to using the morphospecies concept, and one of them is obviously this. You know, in the opinion of a competent systematist, which basically means that it is a very, very subjective thing, and one systematist says that, okay, these two organisms are two different species. Comes another person and says, "No, no, no, no, this is just one species; we lump them together, right?" So, obviously, if you have something that is arbitrary. Then it becomes difficult for anybody to keep track of whether two organisms are the same species or not. The second set of problems related to the morphospecies concept is again related to the nature of the variation that we see. and I will talk about two slightly different but actually allied kinds of problems over here.

The first of them is related to what is known as cryptic species or sibling species. So, what I am showing you here is a particular species of *Anopheles* mosquito known as *Anopheles maculipennis*. And as you can see, it is found very commonly in Europe and New Zealand, and it is an anopheline. So, it transmits malaria. However, when people actually looked at this species, you know, closely morphologically, it is just the same.

But when they collected species from different areas and looked at their molecular characteristics, they figured out that actually, what we think of as *Anopheles maculipennis* is not one species; it is a cluster of nine different species, only some of which transmit malaria. In other words, these consist of nine different groups that have evolved separately from each other, you know. Millions of years, actually, but morphologically you cannot distinguish between them. So, this leads to, you know, this is an example of what is known as a cryptic species. where you have two or more distinct species that are classified as a single species due to the fact that They are very, very similar to each other, and their morphologies are indistinguishable.

Now, as I said, you know this figuring out that *Anopheles maculatus* actually is nine different species. is something that is very important from a very practical point of view because Only a small subset of those nine are transmitting malaria; many of them are not. And therefore, obviously, in all those areas where you have that species that is not transmitting malaria there. You do not really need to worry about it, and you can focus your effort on controlling them only in those areas. where you have the species that is transmitting malaria.

The other issue with the morphospecies concept is that it is completely 180 degrees from this, which is best illustrated by this figure. I am showing you three photographs of owls, and I ask you the question: how many species of owls are here? Now, if you look at this closely, you can see that this one has a very prominent ear kind of thing. These two do not seem to have them. This one obviously has a very different shape and a very different color. And if you look at its mouth features, this one is slightly reminiscent of this one.

But color-wise, actually, all three of them—this one and this one—are gray, but the patterns are very, very different. So, depending on whether you are a taxonomic lumpers or a splitter, you will probably end up saying that you know all three of these. There are different species, or you might end up saying that you know this one and this one; the colors are roughly gray, white, etc. Sure, this kind of ear thing is not there. But it may be based on color; I will make this one and this one A and C as one species, while B will be a different species, and so on.

However, if you actually study these animals in their native habitat and look at them closely, You will find that these two are actually the gray and rufous morphs of the same species. Which is known as the eastern screech owl, *Megascops asio*. Why am I calling them the same species? That is because if you look at their calls, they have exactly the same call; they can interbreed with each other. And when there is interbreeding, the brood can have the same morph simultaneously. which means that in the same nest, you can have some of the babies of This morph and some of the babies of this morph are coming out of the same parents, which Clearly tells you that these belong to the same group of

organisms.

On the other hand, if you take the third one, this one, this is what is known as a Western Screech Owl, *Megascops kennicottii*. And this thing actually has a very, very different call compared to the eastern screech owl. There are no known intermediates that have ever been observed between the eastern and the western screech owls. And more importantly, if you look at their mitochondrial DNA sequence, You can see a huge amount of difference between these two and this, whereas there is no difference between these two. So, this is why it makes sense to group these two together in one species, whereas this one is taken as a separate species.

Although if I just go by morphology, which I have to, for example, if I were looking at museum specimens, then I will either call them. One species, two species, three species, or whatever, but most probably I would not come to this distinction that I am making. So this kind of thing is what, you know, is taken care of by another species concept: the biological species concept. So, if you remember, I told you that the morphological species concept is very, very arbitrary. So the biological species concept tries to remove this arbitrariness by saying species are groups that actually are or potentially interbreeding natural populations that are reproductively isolated from other such groups. So the main criterion over here in this definition is reproductive isolation. which implies an inability to exchange genes, you know, between the populations. Now this is obviously a much better definition in terms of its objectivity because reproductive isolation is something. That technically does not really depend on the arbitrariness of, you know, which taxonomist you are talking to.

But on the disadvantage side, it is very, very difficult to unambiguously know. Which species can exchange genes and which species cannot? Most of the time when we say that, "Hey, these two are two different species," we haven't really You know, I tried to make them or have not really observed them extensively enough to know that they do not interbreed. We are just making a guess; we are saying that we do not think that they interbreed. And although many times those guesses work out, often they do not. And one

big example of that is the fact that many species that we think are reproductively isolated, If you actually make them mate, they will mate and they will produce offspring.

So here are two major examples of this from the same two species, lions and tigers. Now, based on their morphology and behavior, anybody will tell you that lions and tigers are two different species. If you take a male lion and a female tigress, they will breed and produce cubs known as ligers. ligers for males and ligesses for females or you take male tiger and female lioness, They will produce fertile offspring known as female lions. And as I said, you know, many times people think that, oh okay, the hybrids will not be fertile.

But I just told you, and I am repeating that both ligers and tigons can be fertile. It has been shown that they can be fertile. So, this means that many times when we are applying a biological species concept We are applying it again using some kind of guess; we are not really sure whether that guess will work out or not. The second kind of issue that happens related to the biological species concept is one that is known as a ring species. Now, what is a ring species? So, as the definition tells you, a ring species is a connected series of populations where the neighboring populations can interact with each other, But the two populations at the end of the series are too different to interpret. So this actually creates an issue in the context of the biological species concept. Now let me give you an example and show you what I mean over here. So around the Arctic Circle, there lives a kind of bird known as gulls, sea gulls. So there is one particular genus of those known as the Larus gulls.

So if you look at those Larus gulls around the Arctic Circle, you will find that there are seven different species among them. These are morphospecies. So, these are, you know, 1, 2, 3; these are the 7 species that we are talking about. And you can see that they are found in slightly different places. Now, the nearby ones can all exchange genes with each other; they can hybridize with each other.

So 1 can exchange genes with 2, 2 with 3, 3 with 4, 4 with 5, 5 with 6, 6 with 7, right? So, first of all, that means that since they can exchange genes, then 1 and 2 are the same

species. 2 and 3 are the same species; 3, 4; 4, 5; 5, 6; 6, 7 are all the same species. So, biologically speaking, we should say that these belong to the same species. But we have a problem. What is the problem? The problem is that 7 and 1, so these species, when they come together, cannot interbreed.

So, for example, here I am showing you this; this is the 7th, what is marked as 7 over here. This is *Larus argentatus*. and this one is what is marked as 1 over here, this is the lesser black-backed gull. And it turns out that these two, even when they come close to each other in certain parts of Europe, are not able to interbreed. And as I said, this is a problem according to the biological species concept because, by definition, you know. If they are all able to interbreed with each other, 1 and 7 should have been able to interbreed with each other.

So, according to the biological species concept, these two, you know, from this side do not belong to the same species. Yet if we go by this side, they are actually supposed to be part of a continuum. and therefore, they are supposed to belong to the same species. So, this creates a definitional inconsistency in the ring species, which is why it is one of the problems of the biological species concept. Now I must caution you here that although this is a textbook example, *Larus* gulls are a textbook example of ring species.

There is some debate about whether they can truly be called ring species. However, that example notwithstanding, this kind of situation has been seen in many other cases. And therefore, one can say that the biological species concept can lead to the problem of ring species. Now, one way to solve both these problems that we see in the biological and morphospecies concepts is One way to solve this is through a third species concept known as the phylogenetic species concept. So, what exactly is the phylogenetic species concept? I will explain it to you with an example.

So suppose you have 5 different populations and you want to see how many species there are among these 5 different populations. Do all five belong to different species, or do you know if there is some other relationship here? So let us call these 5 A, B, C, D, and E. So

what you do is take them and, based on either their morphological characters or their molecular data, You create phylogenetic trees out of them. So let us assume, just for a moment, that the phylogenetic tree looks something like this. So in this particular case, you can see that A is one monophyletic group, and E is another monophyletic group which basically means they have a clear ancestor; A has a clear ancestor over here, and E has a clear ancestor over here. B, C, and D, all three of them, have the same ancestor, and you cannot really distinguish between them. B, C, and D based on whatever characters you have used to make this particular tree. So, in this context, I can now define a phylogenetic species as a tip on a phylogeny. which implies the smallest set of organisms that share an ancestor.

So, you know these organisms that share an ancestor. and can be distinguished from all other such sets, as you can see over here in the context of the tree. So, A is a phylogenetic species, E is a phylogenetic species, and B, C, and D together are one phylogenetic species. Therefore, in this tree, there are three phylogenetic species. Now, of course, a phylogenetic species means explicitly taking the evolutionary relationship. And the divergence into consideration while it delineates for species.

Now, on one hand, this is very good because, you know, it can take care of cryptic species, provided you have appropriate resources. Molecular data for them works for sexual as well as asexual species; it also works for, you know, existing or fossil species. Remember, the biological species concept only works for sexual species; it does not work for asexuals. The biological species concept assumes something about reproductive isolation, which basically means For fossil species or museum species, you cannot figure out anything about whether they could have exchanged genes or not. Which means the Biological Species Concept (BSC) works only for sexual species and nothing else. whereas the phylogenetic species concept can work for cryptic, sexual, asexual, and fossil species. The morphospecies concept works for everything except cryptic species. So obviously it looks like the phylogenetic species concept is the best one. The one that you know takes care of pretty much all the problems we talked about. However, if you think about it closely, it again has a few cons.

The first and most important problem is that you need a lot of information to make your phylogenies. And sometimes you know if you have let us say only one specimen or two specimens out there, it becomes very difficult. To get that much information, you cannot really make phylogenies out of just one or two specimens. So, practically speaking, making these phylogenies difficult, and for any phylogeny, it is also going to be very subjective. It will depend on which traits you have chosen; it will depend on which methods you have chosen for making your trees, and so on.

And therefore, these things are extremely, you know, subjective, just like the morphospecies concept. And typically, it has been observed that depending on how you make the tree, to some extent, but, Typically, they end up inflating the number of species quite a bit. Now, of course, you know some people say, "So what is the problem if it is inflating? If it is inflating, why is that a con?" It is not a con per se, but again, as I said, it depends on how much inflation is happening. depends critically on which method and which trait you are using to construct your tree. And in that sense, it is very, very subjective, and you can end up pretty much having, you know, any number of species.

Depending on whether you play around sufficiently with your number of traits and tree-making method. So, in that sense, subjectivity is the primary con here. So, what do you conclude from this brief discussion? So, the main conclusion is that there is really no single way of looking at species that is both. Objective and practically implementable over all species, we talked about just three of them here. Remember, there are some 24 to 26 definitions in total of species, and for none of them do you have this property.

So, none of them is both objective and practical, and that is why taxonomists use different definitions of species. Based on the context in which it is being used, based on how much information is at hand, and so on. So, there is no single way of thinking about species; it is all context-specific. Now, given that we go back to our original question about how a new species formed and what. The formation of a new species obviously depends on which species concept is being used.

So, for example, if you have the morphospecies concept, which is how Darwin thought about it. So, Darwin was saying that species are different if you know they look different. Now, if you think about it, then the Darwinian processes that we talked about—selection, drift, migration, etc.— That is sufficient to lead to major differences in terms of the distribution, such that at some point. You will put an arbitrary cutoff and say here one species ends and there another species begins.

Therefore, what Darwin talked about in *The Origin of Species* includes those things along with, you know, various others. evolutionary forces that we talked about that are sufficient to explain speciation according to the morphospecies concept. Similarly, if you look at the phylogenetic species concept, all it is saying is, you know, Whatever is coming out as separate tips and branches in my phylogeny, those are the species. So, it is in some sense taking, you know, a bunch of observations, and it is post facto declaring them as species. And for that too, what Darwin ended up, you know, postulating, all those forces are sufficient.

To form species according to the phylogenetic species concept. So, it is only according to the biological species concept that reproductive isolation is the main factor. That is where we need to, you know, think about how species are formed. In other words, if you take Darwin's processes, selection and others, those do not really tell you how reproductive isolation can evolve. There, in the modern synthesis, the whole assumption is that If the process continues for a long time, then at some point, reproductive isolation will set in. It is more like hope, but there is nothing that guarantees reproductive isolation will set in.

So much of this entire thing about, you know, speciation and the formation of new species actually boils down to Question about what the various mechanisms of reproductive isolation are. And how exactly do they evolve in species? That is what we are going to look at in our next discussion. See you there, bye.