An Introduction to Evolutionary Biology

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Week 1 Lecture 1

Introduction to the Living World and two major questions

Welcome to the first lecture of an introduction to evolutionary biology. Now, before one begins to talk about any subject, it's typically a good idea to get an overview of the questions or the kind of questions that the subject is trying to answer. In other words, what exactly is evolutionary biology trying to explain? Now note here that we are not talking about the process of evolution here, we are simply talking about the subject called evolutionary biology, what is it all about. Now, typically when one is trying to answer such a broad question, bird's eye view of a subject, then it is a good idea to take what I call as the alien's view. So, assume that you are this alien and say you are a master student in whatever planet you come from. And for your master's dissertation project, you have been told to go to this planet called Earth and then figure out about the various life forms over there.

So you sit in your nice little ship and you come to earth and if this were a Hollywood movie obviously you would have landed in the US but since this is a NPTEL course let us assume that you land somewhere in India to be more specific let us assume that you land in the western part of the country. So, in the western coast we have this mountain range called the Western Ghats and so you land somewhere on the Western Ghats and you come out of your ship and this is what you see. So, you see this some kind of a green thing and you soon learn that the locals call these trees or plants and you start asking the question that okay what kind of life forms can I find over here. So, you start going across

you know exploring the whole of Western Ghats and you come to places like these.

This is the famous Kaas Plateau in Western Ghats. You see that it is full of flowering plants. You move around a little bit more and very soon you figure out that in the Western Ghats among other things you seem to have lots and lots of flowering plants. So, you categorize 1400 of those over there. You also find about 1800 non-flowering plants, you find about 6000 insects, about 290 fishes and so on and so forth.

So, basically you find a huge number of life forms. You ask yourself that okay maybe you know what these guys call land they obviously there are lots of life forms on that. But when I was coming with on my ship I found that most of the surface of this planet is covered by water. So, do I also find these many life forms in water? So, you again get into your ship and you again go around and this time you land near Andaman and Nicobar islands of India and from you know while landing from your ship you see this is what it looks like. So, these white things over here these are the clouds and this is the island and again you see it is pretty green.

But what you are really interested in are these parts you know the water near these islands and when you go inside the water what you see looks something like this. Again huge number of life forms and you start cataloguing them and you find about 424 species of corals, some 227 species of phytoplanktons and so on and so forth. So, you come to the conclusion that okay just like land even the water environment seems to be supporting a lot of life. Then the only other thing that remains is air. So, you again get into your spaceship and you start moving around and this time you land in Arunachal Pradesh in the north eastern part of our country and to be more specific you land at this place called the eagle nest wildlife sanctuary.

So, when you come out of your spaceship this is how you find the terrain. But you are interested more in the aerial life forms. So, what you do is you go there on a moonless night and you take a big piece of white cloth something like you know about 2 meter by 3 meter, and, you string that piece between two poles you put a light on top of it and then

you wait for about an hour or so and what you find looks something like this. As you can understand these are moths right and just look at the numbers and the look at how many different kinds that are there and this is just about an hour or so of sampling and that is about it. So then you become very very interested and very soon you realize that Arunachal Pradesh actually is one of the most biodiverse places on the whole planet.

It is so biodiverse that actually even today we do not have very good estimate of how many species of plants and animals etcetera are over there. So, you ask Professor Ramana Athreya who happens to be a colleague of mine at ISER Pune and Ramana will tell you something like you know just in eagle nest sanctuary alone forget about whole Arunachal just in that one sanctuary there are about 1500 species of moths and butterflies; About 450 species of birds. This is a very important number because all over India you have about 1200 or so species. But, in Arunachal in that one sanctuary alone you have 450 which is about one-third of the total bird species diversity of India. And another 300 species of ants and the hundreds or so species of mammals and so on.

So, you come to the conclusion that whether I look in the land or I look in the air or look in the water, wherever I look life forms are tremendously diverse. In other words, there are huge number of what earthlings call as species. Now, at this point many of you will probably ask the question that, but these are very chosen examples. Do I get this level of diversity wherever I go on this planet? And the answer is obviously no, you would not get Arunachal kind of diversity let us say if you go into Sahara. However, the primary point that is being made over here that wherever on this planet you go you will find quite a bit of diversity in terms of life forms.

That original point is actually correct, wherever you go you will find lots of species. So, coming back to you as the alien, let us assume that now you are trying to study, you know, a group. Forget about all the diversity that is too much. You will just study one group and try to see what kind of diversity of variation you find within that group. And let us say you start by choosing humans, and the first thing that hits you straight away is diversity in skin color in humans, right? So as i am showing you even in a country like

India there is tremendous diversity in terms of what color your skin is and it is not only about skin color it is also about your facial features it is also about you know how tall people are Whatever trait you look at, you are very likely to find that there is a lot of variation even within a group.

Now, is this something which is true only for humans? Absolutely not. So, for example, if you look at dogs, again you will see a lot of diversity among dogs in terms of how big they are; You know, what kind of fur they have, what is the colour of the fur, what is their temperament, what is their behaviour, whichever angle you choose to study; You will find that even within a species, even within a group, you will find a lot of variation. So, now you realize that variation is something that is all over the place and by this time obviously your dissertation is over, you have probably become a PhD student or more likely multiple PhDs have happened. So, now you say that okay, I understand that when I look at the forms there is lot of variation in terms of the forms. But, what about function? how exactly do these organisms function? So, you choose one organism let us say again you choose a human and you ask the question that how exactly does this organism function.

So, you take the person you dissect the person out and very soon you figure out that in order for an organism to function there are many levels or many kinds of things that are inside its body. So for example we know that in any human there are multiple groups of organs known as organ systems so what i am showing you over here this is the musculature system this is the skeletal system this is the nervous system and this is the circulatory system And all these organ systems they talk to each other, they end up exchanging information with each other and they end up affecting each other. So, the way your bones are going to move depends on your muscle. The way your muscles function depends on what kind of nervous conduction is you know nerve impulses or nervous messages are going to them And how your nerves function depends on what kind of information they are getting from your skin, how your skin functions depends on you know what kind of oxygen is getting to them which in turn depends on your heart and your lungs and so on and so forth. So, all these organ systems they are all connected to each other and that means again there is a lot of diversity out there and more importantly

if you now take any one organ system, let us say you take the circulatory system, the organ system itself is made up of different kinds of organs, right? You have the heart, you have the lungs, you have you know all these blood vessels, the arteries and the veins and so on.

Now you take any one organ, let us say you take the heart, the heart itself is made up of so many kinds of tissues. You take any kind of tissue, the tissue itself is going to be made of so many kinds of cells. You take any one cell, inside the cell you are going to find so many kinds of cell organelles, Basically, even if I take just one organism, even inside that organism, I find a very diverse set of organs and tissues and cells, etc., all of which need to work in a coordinated fashion in order to make what we call life possible for just this one individual. Now, some of you at this point will probably say that again this is a biased example.

Why? Because we already know that humans are one of the most complex life forms on this planet. So, does that mean that if we take something much simpler all this complexity of life just disappears? Answer unfortunately is not really. So, for example, let us take one of the simplest life forms that we can get a single cell bacteria, right. So, as you can see it is just one cell with some you know flagella stuck at one end, but if you now take just this one cell and cut a section what you are going to get is going to look like this and you can see that again inside this there are so many substructures, so many organelles. And now if you ask the question that what is this one cell composed of, the number of chemicals that are inside this cell is actually mind-boggling.

So, you know that any cell is made up of proteins, it is made up of lipids, it is made up of carbohydrates, forget about everything else. Let us just concentrate on one of those, let us concentrate on only proteins. Do you know how many kinds of proteins a bacterial cell has? Forget about the number, just the kinds. So, just to give you some you know idea about what the numbers look like if you take an E. coli cell then as per the genome of the E. coli it is predicted to have about 4400 proteins out of which till date we have detected about 2600 or so. So, which tells you that even at the level of a single cell, there is an

enormous diversity in terms of the molecules that are making life possible inside that cell and this is just the number that I am talking about. Now, if you start thinking about how all these molecules are interacting with each other, to create various pathways and how those pathways then themselves are interacting with each other, you realize that even for the simplest organism what you actually have is a very very mega constellation of things that are all interacting with each other to make life possible. And this, you know, the fact that there are multiple components and the fact that all these components are interacting with each other, this property is what I am talking about as complexity. And what living organism you are talking about, how large or how small, all living organisms by this definition that I gave you are actually ultra-ultra complex.

Now, if we think about complexity in this way. then we actually have a mega problem. What is that problem? I have already told you that there is a lot of diversity across life forms. I have already told you that even within one group, one species, no two organisms are typically alike, there is a huge amount of variation. And then if we now drill down to just one organism, then inside that organism itself we have so much of diversity.

So, if that be the case, how exactly does one study life then? Is not it a study of a humongous amount of diversity superimposed on another humongous amount of diversity, superimposed on another humongous amount of diversity, right? In other words, is not everything unique? So, is there any pattern at all in this overall picture? Turns out that there is, right? Because if the pattern were not there then each thing has to be, each unit has to be studied on its own and that is going to be a very very difficult task. But turns out that there is a very peculiar pattern in this whole thing, okay? I mean there are multiple patterns but I am talking about one particular pattern. Now think about say a bird and think about a fish, okay? So we know that both the bird and the fish are pretty complex correct however if you look at the kind of complexity or the kind of complex features that the bird has you find that most of them are actually geared towards the kind of life that the bird leads which basically means flying around, okay, what do i mean by that? So if you look at a bird pretty much everything in the bird is somehow or the other related to flight. So, think about for example, the shape of the bird's body over here this is

something that minimizes drag when it is flying through the air which is obviously something that helps in flight. Then think about you know this structure called the wing think about all these feathers.

So, these are all you know all the features of the feathers are such that all of them help them in flight. From physics we understand that flight is something that requires an enormous amount of energy. So, the bird has all kinds of modifications inside it which allows it to generate a lot of energy. So, for example, it has these you know sacs known as air sacs which are inside the bones of the bird and these are all connected to the lungs and these sacs and the lungs together is what helps the bird in terms of generating a lot of energy which again is needed for flight. So, again if you look at the you know bone structure of the bird you know they have hollow bones and this also help them in flight because they are very stiff and you know that is also required in terms of their aerial locomotion.

On the other hand look at the fish. The fish is also pretty complex. However, the kind of complexity that the fish has is not geared towards a life in the air. It is actually geared towards a life in the water.

So, the bird lives in the air. So, in the air obviously, you have oxygen in the gaseous form and therefore, the bird is capable of using oxygen in that form. However, the fish because it is living in water, it only has access to oxygen in a dissolved form, dissolved in water, right. And it is much more difficult to take that oxygen you know just via a lung kind of an apparatus. So the fishes have something completely different, they have this thing called gills, which actually allows them to extract oxygen dissolved in water, so similarly you look at the structure of the fish, you look at the scales of the fish, all these are actually things which are helping it in locomotion in water. So although there is a lot of complexity in organisms, the features of all the organisms they seem to be very well suited for the environment in which they are found.

In other words, the complexity is not random complexity. The complexity seems to have

a relationship with the way the organisms live and where the organisms live. So, just to put the four properties together, here are the four properties tremendous diversity, variation within groups, complexity and environmental specific features and to put it simply this is what evolutionary biology studies. So, evolutionary biology tries to understand how this diversity of forms and functions that we talked about how they happen and why is it that the organisms are the way they are. If you look at it closely you will realize that there are you know everything is not making complete sense over here.

Why so? Because remember I said that evolutionary biology studies why the organisms are the way they are, but is not that something that is for example, dependent on genes and therefore, studied by molecular biologists or geneticists. So, I will just explain what I mean here. Suppose, say, you know think about a cow, a cow has horns and think about me I am a human, I do not have horns and therefore if one asks the question why is it that the cow is horned and you are not then the answer to that question is the cow has certain genes which produces horns in them and you do not have those genes and therefore you do not have the horns, right? So, therefore the answer to the question why the cow is like that and why you are not like that lies simply in what genes the cow has versus what genes I have and figuring out what those genes are is something that geneticists or molecular biologists do. So, why are you saying that this is in the domain of evolutionary biology? Extremely nice question. The second important question that comes about is that many of you would have heard a statement in the context of evolutionary biology.

This was made by this famous evolutionary biologist called Theodosius Dobzhansky. It says that nothing in biology makes sense except in the light of evolution. Now obviously this is a pretty big claim but if you think of this as the definition of evolutionary biology. Then it is not intuitively obvious just by looking at the definition that you know nothing in biology will not make sense because of this, right? In other words, fine, why diversity happen and you know why organisms are the way they are? These are nice questions, big questions. But, definitely this is not whole of biology.

So, how is it or why is it that nothing in biology makes sense except in the light of

evolution? Is this statement even correct? And if the statement is not correct, then why is it that people keep on repeating it so much? So, both these are fantastic questions, both these are very interesting questions and in order to answer them, we need a little bit more of information and that information actually is in terms of the history of evolutionary thought. How exactly did people start with those four observations that I talked about, how people tried to make sense out of those observations, how people tried to explain those observations and how those explanations themselves they moved over time. Until and unless we understand those things, we will not be able to answer the question that how is it that nothing in biology makes sense except in the light of evolution. And that is what we are going to talk about in the next lecture. See you. Bye.