An Introduction to Evolutionary Biology

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Week 3 Lecture 11

Classifying variation

Hi. So, after discussing the history of evolutionary thought in the first week and the evidence for evolution during the second week, In the third week, we are going to get into the mechanics of evolution, and more specifically, We are going to talk about variation and why it is important in evolutionary biology. So, suppose you have a population in which every individual is a complete replica of every other individual. In other words, they are all clones and for any trait that you look at, there is no variation whatsoever. So, every individual possesses exactly the same trait, and more importantly, there is no way to generate any kind of variation either. So, if you have such a population, do you think that the features of this population can change over time? If you think about it closely, we will realize that the answer is actually a very, very big no.

And this is the primary reason for which, from the perspective of evolution, variation is a central concept in biology. So, if you remember when our alien was looking at the various life forms on Earth, It found that there is a lot of variation both within a group and across groups. Now, evolution, as we have already defined it, is all about change, and for change to happen, this variation that the alien saw is absolutely mandatory. In fact, one can think about the entire process of evolution; I am talking primarily about microevolution.

As an interaction of three subprocesses through the lens of variation. What are these three subprocesses? First, how is the variation generated? Second, how is this variation acted upon by various forces? So, this is where we talk about things like natural selection, drift, migration, etc. And finally, how is the variation transmitted from one generation to the next? So, these are the three questions that you need to keep in mind when you ask how a particular system is going to evolve. And we will come back to various aspects of these questions throughout this particular course. Now, before we get on with a deep dive into evolution, I am sorry, into variation, It will be a good idea to have some understanding of how to classify variation.

Now, the classical way of classifying variation is what we are going to discuss. And this classical way, in order to understand that, let us you know think about a particular trait. So, the particular trait I have picked up in this case is a variation in skin color. So, what you are seeing in front of you is a South African family, just a single family, and within this family, You can see that there is so much diversity in terms of skin tone and skin color. Now, one can obviously ask the question of what exactly is causing this diversity. where exactly is all this variation coming from? Now, if you think about it, there are three major sources of variation. Some of it is due to variation in skin color right at birth. Which basically means this is due to variations in genes or gene sequences that the individuals possess. Some of it is obviously due to exposure to the environment. So, some people might have experienced a lot of sun; others might have experienced a lot of pollution.

Others might have experienced other environmental features, such as moisture, humidity, or whatever. And because of all these things, we know that these factors can affect your skin color. So, some of the variation might be due to that. And finally, there is a third source of variation about which we normally do not think much. But that source is genetically encoded differential sensitivity to environmental factors.

So, for example, we know that there are some people who, when they are exposed to the sun, nothing really happens. They can walk around in the sun for as long as they wish; they will look pretty much the way they normally look. But there are other people who, when they are exposed to the sun, even for, say, 15-20 minutes, They end up completely becoming red, brown, or whatever other color. So, this is in terms of the variation in how the individuals are responding. Or you know what kind of sensitivity they have in terms of various environmental factors.

So, these three points that I talked about, technically speaking, are important. These are known as genetic variation, environmental variation, and G x E variation. As I said, genetic variation is the result of differences encoded in the DNA. Environmental variation is due to factors that are external to the organism. and factors you know that are affecting how the genes are being expressed and G by E variation, or genotype by environment variation or interaction, is due to the fact that different genotypes People with different gene sequences are differentially sensitive to the environmental conditions. So, we will have a quick look at these three, you know, ways of defining variation. So, when it comes to genetic variation, we have, courtesy of the last 30-40 years of molecular biology and molecular genetics, We have an enormous amount of information about how different sequences can end up affecting both, you know. Different forms of proteins and different expression levels of proteins. And how these can end up affecting your traits, I mean your body size or height or whatever.

Now, this thing—this genetic variation—is something that we are going to discuss in some detail in our next discussion. So, right now we will not go ahead with this, but I would like to make the point that. Classically, this was thought to be the primary source of evolutionarily relevant variation. Because this is the variation that people initially thought was the only kind of variation that could be inherited. People thought that the other kinds of variations were non-inheritable.

However, today we know that that is not exactly the case. And although genetic variations are very important, that is where a lot of our focus typically is. But we have now come to understand that other kinds of variations can also be very important for evolution. And one of the major goals of EES, the extended evolutionary synthesis that we talked about, One of its major goals is to figure out what the role of these other kinds of variations is that we are going to talk about. So, the second kind of variation is variation that is due to environmental factors, and in this context, A particular term is very important; the term is phenotypic plasticity.

What is the meaning of that? So, suppose you have individuals with the same genotype, meaning they have the same genes with respect to a particular trait. And suppose you put them in different environments. Now, sometimes what happens is that the same genotype, If you put them in different environments, they can end up having very different phenotypes. And this phenomenon of the ability of one genotype to lead to multiple phenotypes depending on the environment, This phenomenon is what we call phenotypic plasticity. So, just to give you a visual understanding of the whole thing.

So, look at the figure on the left, the one that says no plasticity. So, on the x-axis, we have the environment; on the y-axis, we have trait values. The three lines that you are seeing are for three different genotypes. Now, as you can see, although the trait values of the three genotypes are different, They do not really change when the environment changes, right? So, that is why they are all flat, and that is why this is an example where there is no plasticity. Now, look at the figure on the right.

Here, what is happening is that as the environment is changing from left to right, the trait values are all decreasing. Which essentially means that whether the value of a particular genotype is going to be high or low. will depend on which environment that particular genotype finds itself in. And this kind of scenario, as I said, is by definition phenotypic plasticity. So, this kind of diagram where you have the environment on the x-axis and some kind of trait value on the y-axis, These kinds of diagrams are known as reaction norms.

So, in this particular example, we are taking the environment as a continuous factor, which is why this has been represented by lines. Sometimes what happens is that the environment is taken as discrete. So, you have one environment that is like one end of the line, and you have another environment that is the other end of the line. So, in both these cases, this kinds of diagrams, these are known as reaction norms. So, we will come back to reaction norms a few times in this course.

So, that is why it is important for you to understand what reaction norms are. Now, do we have any examples of phenotypic plasticity? Tons and tons of them. Turns out that phenotypic plasticity is a very widely reported phenomenon. I will just show you two, you know, kind of eye-catching examples. So, the first example is from a moth called Nemoria arizonaria, and this is a moth.

The caterpillars of these moths are normally found on the oak tree. Now, the interesting thing about this is that it does not have one generation per year; it has multiple generations. So, obviously, some of the generations of caterpillars come out during the spring season. Some of the caterpillars come out during the summer season. Now, during the spring season, the oak tree is in full bloom.

And what you are seeing here on the left-hand side, you know, this is what is called catkins. These are the flowers of the oak trees. Now, very interestingly, the caterpillars that come out during spring, They totally resemble the inflorescence of the oak tree: the catkins. On the other hand, the same caterpillars, the same genotype, when they come out during the summer, When the catkins are no longer there, at that point these caterpillars resemble the oak twig. So, this is a scenario where, due to environmental change, you have two very different phenotypes.

It is not simply, you know, a slight increase in height or a slight decrease in weight or something. It is two completely visually different phenotypes; such a phenomenon is known as polyphenism, right? So, polyphenism is a special kind of phenotypic plasticity in which you have two discrete phenotypes that are created. Another well-known example is a plant called water-crowfoot. Now, this plant is an aquatic plant. And depending on where the plant is during development, it can have very different kinds of leaves.

So, for example, if the leaves were submerged during development, they come out like this. What you see on the leftmost panel, you know, is some kind of networked leaves with a very thin leaf structure. Whereas, if they grow up at the air-water interface, then the leaves, you know, the individual leaflets are slightly wider. And if they grow while growing, they are entirely exposed to air; then the structure of the leaf is very, very different. The leaf body, as you can see, is much flatter.

So, this is another very nice example of how where you are growing can completely change your phenotype based on the environment. So, this was the second type of variation. Now, classically, people thought that this kind of variation, environmentally induced variation, is not inheritable. It cannot be passed to the next generation, and that is why it is not at all important for evolution. However, one of the major breakthroughs that has happened in the field of genetics over the last few years is that Now we know that many of these environmentally induced variations can actually be passed on to the next generation.

Therefore, they can play a potential role in terms of evolution. What exactly that role is and to what extent, we will come back to this when we discuss epigenetics at a later point. But right now, just keep in mind that some environmentally induced variations can actually be transmitted. And then we come to the third type, the so-called genotype by environmental variation. So, if you remember, this is the type wherein, if you have, you know, the environment changing, The phenotypes also change, but different genotypes respond differently to the phenotypes.

So, if you look at the rightmost diagram, you can see that when the environment changes, The trait value is increasing for true traits, the purple and the blue, but it is actually decreasing for the third one, the red one, right? So, this is what is known as a genotype-environment interaction. Do we have examples of this? Again, it is fairly common. So, this is an example from the world of fruit flies, Drosophila. So, this is not Drosophila melanogaster but a related species known as Drosophila pseudoobscura. Now, in Drosophila, they have a belly, and on the belly, they have these bristles.

And different individuals have a different number of bristles. So, what Gupta and Lewontin did was They took 10 different genotypes and made them develop either at 14 degrees Celsius or at 21 degrees Celsius. And then, when the flies grew up, they ended up counting the number of bristles on the abdomens of the males. And what they found was fascinating; they found that for certain genotypes out of the 10, As you went from 14 to 21 degrees Celsius, the average number of bristles went down. Whereas, for other individuals, they went up, and the degree to which they went up or down, So which is determined by the slope of these lines in this particular figure, or which is depicted by the slope of these lines in this particular figure? That degree is very different from the various genotypes, which essentially means that.

The sensitivity is for increasing or decreasing the number of bristles. That sensitivity varies across the 10 genotypes, which is essentially, you know, an example of G by E interaction. I will give you an example that is even closer to us, you know, a human example of this. So, you know that it is thought that if people, when they are growing up, that is during their childhood, If they are subjected to maltreatment, then they end up having mental health issues when they grow up. Now, it turns out that a lot of our mental health issues are related to the amount of a neuropeptide called serotonin in our brains.

Now, the primary gene responsible for the transport of serotonin is known as 5-HTT. And this serotonin transporter gene comes in two different allele forms. One is called S for short; the other is called L for long. Now, therefore, you have three different genotypes: LL, SS, and SL. Now, it turns out that this protein is very important because it removes serotonin from the brain.

Therefore, it is a very important protein in controlling the levels of serotonin here. Now, these two alleles, S and L, as far as, sorry, I shouldn't say genes, these two alleles of 5-HTT, As far as the protein they code is concerned, they code an identical protein; there is no difference. So, the difference between these two is in the promoter sequence for the genes. And because of the difference in the promoters, the individuals who have an SS genotype, They tend to make a smaller amount of serotonin transporter than those who have the LL genotype. Now, because of this difference, it turns out that the sensitivity of these two genotypes The SS and LL genotypes' response to childhood maltreatment is very, very different.

So, if there is, let us say, no maltreatment, Then the probability of developing mental health issues later in life remains pretty much the same statistically. You know, it's not different for SS and LL. However, if there is mild or severe maltreatment, then the probability of developing mental health issues increases. Later in life is much, much greater for the SS genotypes compared to the LL genotypes. In other words, individuals with the SS genotype are much more sensitive to, you know, Developing mental health issues later in life if they experience childhood maltreatment.

Again, a very nice example of how the expression of a genotype depends on the environment in which it finds itself is provided. So, what we have done so far is look at how variation can be classified based on its source of origin. Whether it is genetic, environmental, or an interaction between the two. Now, this is, as I said, a classical way of doing it, and therefore, This kind of predates all the information that we have from molecular genetics. However, over the last 30 to 40 years, molecular genetics has made tremendous advancements; therefore, Today, we have a much better mechanistic understanding of how variation arises.

Now, instead of talking to you myself, I will guide you to a 10-minute-long video called Gene Expression and Regulation. by two real-life sisters, Sarina Peterson and Brianna Rapini. So, on YouTube, they are called the Amoeba Sisters, and this is the link to the video. As you know, the text suggests that the information in this part of the video is part of the course. Now, anybody who is interested in going slightly deeper into this should.

I can recommend chapter 16 from the OpenStax textbook called Regulation of Gene Expression. I mean, the chapter is called "Regulation of Gene Expression." As the slide suggests, the information in this textbook is not part of this course. And therefore, this is only for those people who wish to go deeper. Now, the points that you need to keep in mind are what I am talking about here.

I mean what the video is talking about is essentially a revision of what you might have learned in your 12th grade. The reason I am putting it out here is that some of you may not have read biology in class 12. or you might have read it a long time ago and therefore, you might have forgotten. Which is why it is a good idea to, you know, look at the whole thing one more time just to refresh your memory. The big thing over here is that what this video talks about is important.

Simply in how many ways variation can be generated when you go from a gene to a protein. Please appreciate that when we are looking at traits like height, body weight, skin color, and so on, There are multiple genes available. So, a genotype is not merely one gene; a genotype itself is a constellation of genes. The phenotype is essentially a collection of proteins, not a single protein. Therefore, the process of going from a genotype to a phenotype is much more complicated than what this video and that textbook are going to show you. However, that is something that scientists are still trying to work out, and it is a work in progress. So, see you in the next video. Bye.