Evolutionary Dynamics

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Week 01

Lecture 05

Hi everyone, welcome to this lecture. What we'll do in this video is discuss two really interesting examples. These are also old classical examples, but a lot of new molecular evidence that we have collected for these examples in recent years has shed very interesting light on this. So we will just describe the phenomenology of these examples in this particular video.

And as we go deeper in the course and we actually study the molecular basis of this, we will look at the molecular details which are responsible for the changes in the evolution of these organisms that we are talking about. So the first example, as you can see on your slides, is these pictures of these two moths. One of them is this light-colored moth, and the other one is this dark-colored moth. And these are examples from, these are famous examples from when industrialization first started in England. And what had happened was that the trunks of the trees were light in color pre-industrialization, but as Britain underwent industrialization, there was a lot of soot that was being emitted from the industries that had been set up.

Environmental regulations were not strict, and this soot gradually settled on the trunks of the trees. And prior to the soot settling on these trunks, imagine the following scenario. The trunks were light in color because the soot wasn't settled on them. And moths, there were, when we are talking of these moth populations, there were two kinds. One is this light variant.

Which is this one, and the other one is this dark variant, which is this one. And now, imagine this scenario where the trunk is light. The trunk is also the environment; it's the place where the moths inhabit. So, this is where they live. And while this is going on, which of these two variants

is going to be at an advantage compared to the other one? Remember that these two represent the example of variation existing in the population. Variation in population. That's the first step necessary for natural selection to act, which is satisfied in this particular example that we are looking at. So, as you can probably imagine, when the trunk is light, this light-colored moth has an advantage over the dark-colored moth because of camouflage.

It's just easier to detect a dark-colored object against a light background compared to detecting a light-colored object against a light background. And as a result of this, The population, the predominant population of the moth pre-industrialization, was this. So, this was the predominant population pre-industrialization. And we can draw this in the form that maybe 90% of the population pre-industrialized.

The white background was 90% of the population, and 10% was the dark background. This was happening because the light-colored moth had a greater fitness advantage compared to the dark one. But with the onset of industrialization and the soot emanating from industries, these trunks started getting darker, and as a result, This is what you see in this picture. Now, you can probably realize that it's much easier to detect the light-colored moth against this background compared to the dark-colored moth.

So, the predators are going to find it easier to detect and eat the light-colored moth compared to the darker one. Hence, after industrialization, this variation is now linked with differential reproductive success. Because a white-colored moth is likely to be predated upon much sooner compared to a darker moth, the number of offspring that the white-colored moth will leave will be smaller compared to the black-colored moth. As a result, the fitness, which we described in the previous video as the number of offspring that an individual leaves, will be higher for a black-colored moth compared to the white-colored moth. Because of these two ideas, the frequency of the black-colored moth will now start to increase in this population.

However, we must not forget about the third element here: the color of the moth is a hereditary trait. A light-colored moth gives birth to a light-colored moth, and a dark-colored moth gives birth to a dark moth. So, this is the trait that is inherited, which satisfies the third condition for natural selection to act. As a result of all these three being satisfied and the trunks of trees getting darker in color, what happened was that the frequency of white or lighter-colored moths decreased with industrialization, and the frequency of the dark-colored moths increased in the population. So, that's sort of a classical example that has been studied historically.

But also, it's an example that keeps on being studied even today because now we have the ability to understand the genetic changes that facilitate change in a trait such as the color of the moth. What changes need to happen in the DNA of the organism so that a light-colored moth can acquire this mutation and become a dark-colored moth? So all this progress in technology and our ability to sequence DNA, make sense of the mutations that are happening inside the organisms, means that this is a system that is studied even today. Interestingly, after industrialization, what we are looking at is that the relative frequencies of these two, so this is light, And this is dark.

The relative frequencies have reversed exactly from what they were pre-industrialization. But then, as environmental norms came in and industries were no longer allowed to discharge soot into the air, what happened was that soot deposition on tree trunks reduced again. And as a result, with the growth of the trees, the background again started becoming lighter. So you have this beautiful switch taking place. When the dark-colored moths, because of industrial regulation coming into being, are no longer at this competitive advantage.

In fact, they are at a disadvantage now because they are much easier to detect against the lighter-colored trunks that post these environmental norms, the situation reversed itself and the frequency of the dark-colored moths decreased and light-colored moths increased. So this is the classical example of natural selection in place where all three tenets of natural selection are satisfied and hence you have this almost oscillatory behavior because of human action, first by industrialization and then later on by the introduction of these norms which control pollution. A second very interesting example comes from the US. Again, like the previous one, this is an example that has been studied. In the recent past, these are important publications which have told us about the molecular changes that are taking place in these populations with time.

And the idea is as follows: that in parts of the U.S., Arizona, New Mexico, somewhat the western part, the western southwest part of the U.S., the terrain that organisms live on is quite harsh. So at one end, you have this light sand layer. But what is believed is that about a thousand years ago, so this is over geological time, a thousand years is nothing. So instead of a recent history of this area, there were some eruptions that took place. And because of these volcanic eruptions, some lava came out and settled in various places on this landmass.

So you have this light sand background. But in that area, at some places, you have these spreads where you have this dark lava deposit. And if you imagine this as an area where these two geographical features exist, you will have these little pockets of lava, and this is like several kilometers. So you will have these island-like things, each of which will be one or two, can be one or two kilometers, which are dark terrain. And on the whole, the rest of it is the light sand terrain.

So now, prior to these volcanic eruptions, what was residing in this place were these mice which had this light coat. And that makes sense because a light coat means that they are camouflaged with the background, and it's harder for predators to find them and feed upon them. But with the introduction of this type of background, a light-colored mouse on this background is just so easy to detect for predators that its fitness, the number of offspring it produces before it is predated upon, is remarkably smaller as compared to this dark-colored mouse on this dark lava deposit. This is really hard to detect. This is really easy to detect.

And vice versa, on this light sand background, the dark color is so easy to detect compared to a lighter individual. So what we have in terms of population distribution is that in these areas, it's primarily the dark-coated individuals that live. And in these areas, it's primarily the light-coated individuals that survive. But it's not just that; these publications are interesting because they actually figured out what the molecular changes were that led to the evolution of these dark-colored individuals. And it all has to do with the fact that how much melanin, as a pigment, is produced in the hair follicles that you are producing on the surface of the body.

And melanin generation is simply regulated by biochemical reactions. So, A very, very small change in the DNA of these individuals leads to this change in the biochemical reactions that are taking place inside your body. And as a result of that, the hair follicles that you are producing contain much more melanin, and you become a dark-haired individual. So this transition from this individual to this individual was very rapid, and the molecular basis of it is not difficult to happen at all.

So a very easy transition from one phenotype to another phenotype ensures survival in conjunction with the environmental change that took place in this particular geographical region. So this is another example where The population had no variation to begin with. The entire population was light-colored. Then you had these eruptions take place.

But then, because of eruptions—I mean, prior to the eruption—if you had a dark-colored individual, it was really small and was easily predated upon. So its frequency was small. It was easily predated upon. However, with the volcanic eruption, these dark-colored individuals had a place to go where their fitness was high. And as a result, in this entire area, both these variations coexist depending on whether they are occupying the light sand or the volcanic ash.

So this is another example of natural selection acting in an ecological niche, not inside a lab. And we know how this happened in quite some detail. The last thing we will discuss before we wrap this lecture up is this idea of types of selection. Selection can act in different ways. And I just want to spend a few minutes discussing that before we wrap up this lecture.

The first is called directional selection. The first is called directional selection. And in this one, what is happening is that If I am looking at a trait X on which selection is acting, and this is the percentage population, the initial distribution of this trait in the population is looking like this. But.

Because of what house election is acting, these individuals are at a higher fitness compared to individuals with lower values of X. Hence, as evolutionary time progresses, as generations keep moving forward, these individuals increase in frequency. These individuals decrease in frequency. So there is an overall shift in the population distribution from left to right. And this change can be summarized as that at an earlier generation, this distribution looked like the following. At an earlier generation, this distribution looked like the following.

But as time passed, Because of higher X values, X-valued individuals were coming over at a higher fitness. This population moved in this particular direction. So this is at a later generation. And this is earlier in time.

So this evolutionary change has happened, and the population made a directional movement from my left to my right. And hence, this type of selection is called directional selection. You will notice that in the earlier population, there were no individuals which exhibited values of X greater than this particular value X naught. So you might wonder as to where these individuals came from. These came from new mutations that occurred in the population, which is something that we'll discuss in the next video.

So this form of selection is called directional, where the entire population moves in a particular direction. As opposed to this, you have divergent selection. In this particular scenario, let's imagine that the starting population exhibited a distribution such as this. And now selection acted on this population. So an example that we can think of in this context is, let's say X is beak size.

And at this point in the population, the beak size distribution looked like this. And the primary food that the birds were using to eat was fruits. So an intermediate beak size was very good because it was just convenient to poke holes and peek into the fruit and eat. But if fruit went out, if fruit was no longer available as food, but the food that was available to the birds now was flowers and their nectar and nuts. So for flowers and to get access to their nectar, you need long beaks.

So these individuals are fitter to eat flower nectar. And to eat nuts, you need strong and short beaks. So these individuals are fit when it comes to consuming. So these individuals can grow on nuts. These individuals can grow on flower nectar.

This intermediate is neither fit enough to eat this nor fit enough to eat that. So this is low fitness. In an example such as this, as generations progress, this distribution can take the following shape. This is the distribution of birds with short beaks that are feeding on nuts. This is the distribution of birds with long and slender beaks that are feeding on flowers.

And hence, this type of selection process, which was triggered by the availability of two resources, which selected differentially on the trait that we are looking at, and beak size is obviously an inherited trait, because of this selection, The population was split into two. It started as one unit, but because of the pressure that was applied on the beak, you either needed to have a really short or a really long beak; intermediate wouldn't do. The population split into two parts, and hence this is called divergent selection because half the population was pulled in this direction and another fraction was pulled in that direction. So divergent selection often results in this split in the population.

And the third type of selection is called stabilizing selection. And this is the exact opposite of what we just discussed. So let's imagine our bird population again, that they are consuming fruits, and there is this distribution. Now, any variant that is produced, so these populations are well adapted to consume their food resources and grow. Any variant that's produced here is of very low fitness because that's too short a beak.

It can't really reach into the fruit. Any variant that's produced here has too long a beak. It's too slender, too fragile, and not strong enough to open up the fruit. So these variants are going to be eliminated by natural selection. So in stabilizing selection, what happens is that you have a distribution of that trait, and any variants that come up are quickly eliminated by natural selection.

So the population distribution, as time progresses, actually remains where it started from and doesn't move. That's why it's called stabilizing selection. And the distribution remains largely identical to what it started with. These variants are quickly eliminated by natural selection. And through the course of our videos, we will discuss several examples of selection in action, and it will be an interesting exercise for us to be able to pin down these manifestations of selection as to which of these three selection regimes any particular case falls into.

Next video onwards, we'll start with a little crash course in biology so that we understand and are able to discuss the molecular changes which drive evolutionary change in populations. Thank you.