

# **An Introduction to Evolutionary Biology**

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**Week 3 Lecture 18**

## **Non-genetic Inheritance**

So, until now, we have primarily looked at genetic variation and mutations in them, and so on. So, now we are going to look at a very important class of factors, you know. Inheritances have become very important due to the knowledge that we have gathered over the last four or five decades. And if you remember, we were talking about the extended evolutionary synthesis. A lot of the focus of the extended evolutionary synthesis program is on these non-genetic inheritances. Now, what exactly do I mean by non-genetic inheritance? So, any effect on the offspring's phenotype brought about by the transmission of factors other than DNA sequences from parents or more remote ancestors.

So, that is more or less the definition of non-genetic inheritance, essentially anything that has nothing to do with DNA sequences. Now, what could those factors be? So, there are quite a few, and I am, you know, basing this treatment on this particular reference. That I have given at the bottom of the screen. So, a quick run-through of the list of factors.

The first and very important set of factors is epigenetic factors. We are going to deal with this in a moment. So, I will not talk about it right now. The second thing is cytoplasmic or somatic. So, you know that you know when a zygote is formed in a sexually reproducing organism.

The primary contribution from the male gamete is the DNA. Whereas the cytoplasmic factors come primarily from the female gamete. And you know there are lots and lots of proteins and other things in the cytoplasm of the mother's gamete. which ends up having lots of effects on the phenotype of the organism and the offspring. So, all of those are part of non-genetic inheritance for an organism.

Similarly, in many organisms, the parents end up providing nutrients to the offspring and the quality of the nutrients. That they provide ends up having a lot of effect on the phenotype and the evolutionary outcomes for the offspring. So, those are another set of things. Then, there is a lot of extra organismal environment that the parents provide for their offspring. So, for example, you know that insects, when they are laying their eggs, choose sites for egg laying, and it has been shown that the success of the offspring depends a lot on what kind of site the parent chooses. Similarly, the kind of nests that the parents build for their offspring. Where they build it, and you know all those factors have an effect on the offspring and its success. And finally, of course, we have culture and behavior. So, in this context, the two factors that are the most well-studied.

The ones that have the biggest ramifications are the first and the last: the epigenetic one and the culture and behavior one. So, that is what we are going to focus on in the remaining part of this discussion. So, what do I mean by epigenetic inheritance? What are epigenetic changes? So, changes in gene expression happen without any corresponding changes in the DNA sequence. So, there are many kinds of such epigenetic changes. So, I will just talk about three major types, I mean, this is just a revision for many of you. So, one type is DNA methylation, where methyl groups are added at various places on DNA due to different environmental factors. These environments can be external to the organism or the internal environment of the organism. But all these factors add these methyl groups, and then these methyl groups, The presence or absence of these methyl groups can affect the rate of transcription of these genes. And this rate of transcription of these genes can, in turn, have major effects on the phenotypes, then, of course, you have all kinds of histone modifications. So, you know that histones are proteins on which the DNA is coiled like this. So, if you have, you know, various groups, such as a methyl

group or an acetyl group added or subtracted from the histone, Then all these things affect, you know, the tightness with which the DNA is coiled around the histone protein. And that tightness, in turn, has an effect on gene expression rates. The third thing is what is known as microRNAs.

So, these are 17 to 25 nucleotides long pieces of RNA, and it has been shown that They play a very major role in multiple biological processes, including the regulation of gene expression. So, the mechanism of epigenetic regulation is a fascinating topic. Unfortunately, it is not very directly relevant to this course. So, for those of you who already know about it, great. For those of you who haven't, you know, learned about it in previous biology courses, I will direct you to this video by the Amoeba Sisters, a very basic introduction to epigenetics.

However, the notes that they have below the video. They actually link you to much more advanced papers and references on epigenetics. So, if anyone is interested in that topic, you can look up those notes as well. Otherwise, it is a very basic introduction with lots of nice examples that I am not covering here. So, you should definitely take a look at it and anyone who wants to go slightly deeper than that, this is a very nice website, very basic. Even people who have never studied biology can understand what epigenetics is. And how it affects evolution very nicely from this particular website. Although this link is a University of Utah link, it is not a requirement for this course. But I strongly recommend that you go and have a look at it.

Okay, so in the context of this course, what matters is how it means epigenetics and how it impacts evolution. Now, to have an impact on evolution, as I have already said, things need to be inherited. Now, the question is whether epigenetic traits are inheritable. So, for a long time, people thought that epigenetic traits were non-inheritable. Why did they think like that? That is because during the formation of the gamete, But after the formation of the gamete during the early developmental phase, the epigenetic marks that are present in the male gamete and the female gamete, Those epigenetic marks are actually all purged.

So, this is what is known as epigenetic reprogramming. And therefore, for a long time, people thought that epigenetic marks could not really be inherited across generations. However, at some point, people started realizing that this was not entirely true. Some epigenetic marks do end up escaping the epigenetic reprogramming, and that is when people started looking for them. And when they looked for it, they realized that transgenerational epigenetic inheritance is very much possible.

It is not extremely widespread, but it is there. It is there in reasonable numbers to suggest that it will be important. Most of the examples are from the plant world, where the germ-soma separation doesn't really happen very early in development. However, even in the context of animals, there are some examples. Now, in most cases that we know about, the marks do get reset.

Even the ones that are transgenerationally being inherited, even they are not stable like mutations. Even when they have been transgenerationally inherited, after a few generations, they end up being reset. And that is why people think that maybe you won't see any long-term patterns regarding epigenetic modifications. However, recent studies suggest that this may not always be true. There are certain very notable exceptions, and I am showing you one very notable exception here.

So, we know that the genetic sequences between humans and the great apes are similar. The gorillas, the orangutans, and the chimpanzees are very, very similar. However, if you look at the phenotypes, the phenotypes and behaviors are pretty different. So, people have always wondered: could the phenotypic differences between these great apes? Be a consequence not of genetics, but actually of the epigenetic marks or epigenetic patterns. So, these people, Hermandó-Herraez et al., actually compared the methylation pattern of humans. With four different species of great apes: the chimpanzees, the bonobos, the gorillas, and the orangutans. And what they found was fascinating. So, the first thing they found was that there were about 800 genes that had species-specific methylation patterns. Of these, 171 genes had methylation patterns that were unique to humans.

So, there seems to be some correlation between being a species and the corresponding methylation pattern that one has. However, more importantly, there were 184 genes between chimpanzees and humans for which there was no difference at the protein level. The protein sequence is exactly the same, and yet there are significant epigenetic differences between these two species. So, all this and these are mostly genes that are related to early development or formation of the nervous system.

So, these observations indicate that epigenetic alterations can very well be an extremely important force, at least during primate evolution. We will now have to go out and check for other species, but as far as primates are concerned, they look to be very, very important. However, what is the current status of epigenetics? Remember, I told you that extended evolutionary synthesis is trying to see if the You know, the paradigm of evolutionary biology, the modern synthesis, needs to be expanded, or a new paradigm needs to be created. And one of the major things that they talk about is epigenetic inheritance. So, if you look at the current status in the field, the previous example notwithstanding, Many scientists are not really convinced that epigenetic changes will play a big role in evolution or have played one.

Now, why do they think like that? There are two major reasons. One, as I pointed out, most epigenetic marks are not very stable over time. They can be inherited for a few generations when they can be, but after that, most of them just dissipate. And mind you, not all of them are inheritable to begin with, and the ones that are inheritable are not stable. So, obviously, the argument is that if something is that unstable, then is it going to be of any use evolutionarily? The second thing is that many people have thought or argued about what exactly is happening with epigenetic marks.

They are going from, you know, methyl present to methyl absent, or acetyl present to acetyl absent, and so on. So, if that is the case, can you conceptualize all these epigenetic changes? Essentially, as mutations with a very high rate of reverse mutation? In other words, you know what we were talking about since you know A1 to A2 and A2 to A1.

So, think of the methylation patterns, or whatever the epigenetic patterns, as 0-1, on-off. So, when you are going from one state to another, call it a forward mutation. When you are going back to the original state, call it a reverse mutation.

And essentially, all we have is a system in which the rates of forward and reverse mutations are extremely high. Now, what is the implication of thinking about it in this way? The implication of thinking about it this way is that then. You can essentially treat epigenetic modifications as specialized mutations; that is about it. You do not really need a complete paradigm shift to handle epigenetic modifications within the framework of evolutionary theory. And there are others who feel that it is probably not that easy, and this is a phenomenon that requires a lot more investigation.

So, they have come up with different ways of conceptualizing evolution in which epigenetic modifications are involved. can play a much bigger role compared to what people who are more into modern synthesis think they will play. So, the bottom line is that this is very much an active area of research. People are still making models; they are still speculating; they are still gathering data, and as of now, the jury is still out on this one. So, the second thing that we are going to talk about is cultural/behavioral inheritance.

What do I mean by that? So, a cultural inheritance is an inheritance system that is characterized by the storage and transmission of information. Communication, imitation, teaching, and learning. In other words, what is being passed on across generations is some form of information. Now, the biggest example of this is obviously us humans and the civilization in which we live.

I mean, just think about it. You know, Charles Darwin died a long time ago, and yet Charles Darwin's ideas are reaching you today. So, there is an inheritance of his thoughts from him to you via me in this particular case, and none of us ever saw Charles Darwin. So, if you look at our entire civilization around us, all of it is built on the knowledge that has been gathered across generations. and transmitted across generations, both knowledge

and technology that have been transmitted across generations. And in that sense, you do not really get your inheritance only from your parents. You can get your inheritance from anyone, including people who have died a long time ago. In that sense, this kind of inheritance is a cumulative factor. As long as there is a way of storing the knowledge, this kind of inheritance is cumulative, which makes it very, very powerful. You know a way of generating variation, a very, very powerful way of changing the way we interact with our environment. And in that sense, cultural and behavioral inheritance is a qualitatively different beast compared to all the genetics, and other kinds of inheritances that we have talked about up to this point. There are, you know, several examples; I mean, whatever I was talking about primarily was in the context of humans. However, we have to appreciate that there are quite a few examples from the world of nonhumans too. And I am going to give you just two of them. So, the first example is tool-use behavior in chimpanzees.

So, we know that chimpanzees use many different kinds of tools in their natural environment. But where do they get that knowledge? So, here you see that a chimpanzee is poking a twig into a termite mound to catch termites. Now, people thought that this was a very easy thing to do until scientists actually took twigs. And started poking them in termite mounds, and to their horror, they figured out that it was actually very difficult. It is not easy to just poke, pull a twig, and twirl, and the termites will come out.

No, there is a way of doing it and that specific way of doing it is what the chimps learned from their moms, particularly moms. But instead of me telling you about this, I think you should listen to it from the OG Jane Goodall. So, Jane Goodall is the person who actually showed for the first time that Non-human animals, in her case, chimpanzees, can use tools. This was a very, very important moment in biology. Because prior to that, one of the definitions of human beings was that they are the only organisms which can use tools. and Jane Goodall showed that that is not really correct. And after that, of course, there are many, many other examples of other organisms. Particularly birds use all kinds of tools for all kinds of purposes. But this realization that we are not the only tool making organisms on this planet was A massive sobering factor for much of humanity, and this is

the lady who actually did it. So, for that reason alone, you should go and look at this particular video. Where she talks about how cultural inheritance occurs in terms of tool use in chimpanzees.

So, the next example that I have is the spread of a new song in a species of bird. We call it the common name for which is the white-throated sparrow. So, this species of bird is found primarily in Canada. It has a very long range from one end of Canada to the other end of Canada. Now, this particular bird, as you know, all birds have a particular song; I mean, most birds' songs are very specific.

So, this particular bird before the year 2000 had a song that had, you know, three-syllable motifs, right? So, you can see over here in this particular upper sonogram. So, the song primarily had substructures, each composed of three motifs. As they are called, three syllables in some sense. However, somewhere around the year 2000 and in one location, Somehow, there was a bird or a group of birds that developed a two-syllable song, which is what you see in the lower panel. So, you can see that it almost looks like two of the syllables joined to form a longer syllable.

One syllable was, roughly speaking, what it was earlier. And this second song, the doublet song, for some reason, the females probably preferred it, and once that happened, Within 15 years, that song actually spread from one part of Canada, the western part of Canada, All the way through the mid part, all the way, I mean almost to the eastern part. So, now only the eastern part of the coast of Canada and the US. That is where you find some populations that are still singing the old song, but otherwise, within 15 years, Much of the North American continent has been swamped by the spread of this two-syllable song, right? Now, we do not really know why exactly the sparrow females prefer the two-syllable song over the three-syllable song. Maybe there is something very sexy about it or something very melodious about it to the sparrows' ears; we have no clue. But what we understand is that, culturally speaking, one kind of song has been replaced by another kind of song.

So, how does it, and in this case it means cultural evolution, sorry, cultural inheritance, how does it impact evolution? So, cultural changes have a few properties that make them very different from normal genetic changes. So, as I said, cultural changes can be generated, and they can spread very, very fast. They can be transmitted even after the originator has died, and they can actually be transmitted to totally unrelated individuals. This is very important because all the genetic stuffs They are primarily transmitted from the parent to the offspring.

This is what is known as vertical transmission. However, in this particular case, they can be transmitted. Cultural things or behaviors can be transmitted to totally unrelated individuals. The biggest examples of that can be seen from all kinds of fads that are passed on. In the name of fashion or in the name of, you know, the cool thing, etc., all those are actually cultural inheritances. So, since culture and behavior, at least some of which can change the survivorship and reproductive capacity of organisms, It is abundantly clear that they can potentially affect evolutionary outcomes; everybody knows that. However, in what precise way and to what extent does it affect evolution, particularly in those organisms? where we do not have any major reason to believe that they have a massive culture or anything. This we have still not entirely figured out. Even in the context of chimpanzees, Caledonian crows, and other birds that have a rich culture, It is still not entirely understood how it is impacting their evolution. Again, like many other things in extended evolutionary synthesis, this is something that is a very active area of research, and hopefully, some of you will be able to contribute to it if you end up becoming evolutionary biologists at some point. So, with this, we come to the end of module 3. We have looked at different kinds of variation that exist. We have looked at what happens to genetic variation in the absence of any evolutionary forces.

Basically, nothing changes the Hardy-Weinberg equilibrium. We have looked at how new variation is generated and how that affects evolution, particularly in the context of mutation. In today's discussion, we looked at non-genetic inheritance. So, now in the next module, we are going to look at probably the most important. And certainly the most

well-studied evolutionary force is selection, and that will be the next discussion. See you.  
Bye.