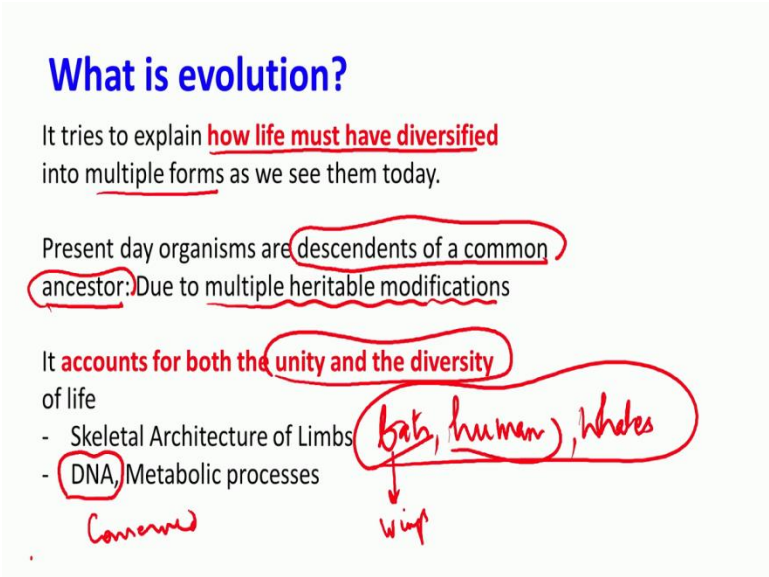
**Biology for Engineers and other Non-Biologists**
**Professor Madhulika Dixit**
**Department of Biotechnology**
**Indian Institute of Technology, Madras**
**Lecture Number 03**
**Evolution-2**

So welcome back to this course on "Biology for Engineers and Non-biologists". In the last video we spoke about origin of life and how they, life evolved from non-living things, essentially through chemical reactions, and then the ability of these early synthesized molecules to self-replicate and eventually formation of protobionts and then the early form of life. In today's video, what we're going to talk about is that how from this early form of life, the life evolved to the present day organisms and there's a huge array of them; it's not just one just bacteria, you see that the life (ex) expresses itself in multiple forms.

So what is it that caused this variation, this distribution in different life forms, and that is evolution. Now, evolution is a very important subject and topic to study, and I would like to start this particular class by quoting Theodosius Dobzhansky, that "Nothing in biology makes sense except in the light of evolution". What you'll appreciate hopefully by the end of this class is that though we have these different forms of life, its evolution which has played the key role. And mind you, this evolution has not happened overnight, this evolution has happened over billions of years. So coming to evolution, and what is evolution?

(Refer Slide Time: 04:15)

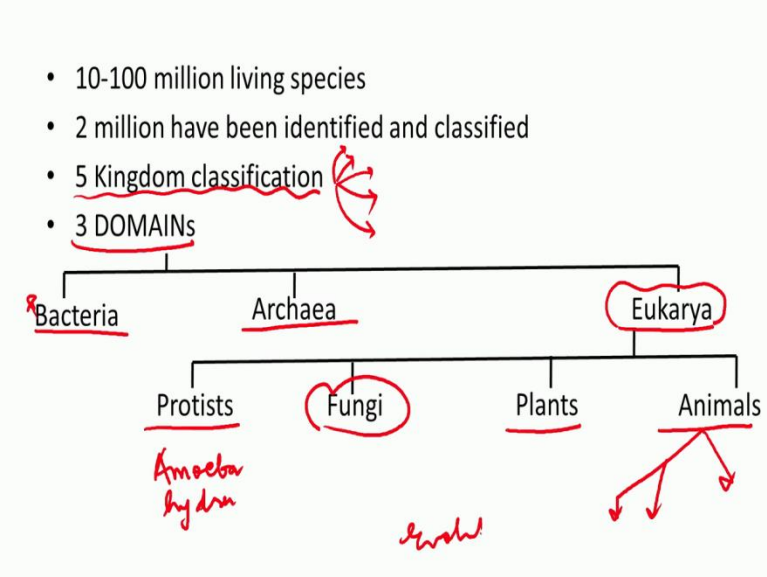


Evolution essentially tries to explain, let me go to the point, okay, it tries to explain how life must have diversified into multiple forms as we see them today. And these present forms are believed to be the descendents of a common ancestor. Now how does this happen, how did these descendents came from a common ancestor. We believe, during the course of history of earth's life, a lot of changes happened in organisms which went on, which went on being passed on to subsequent generations.

In other words, multiple heritable modifications from one generation to the next, and it is this evolution which essentially accounts for what you call as the unity and the diversity of life. Let me give you an example. If one were to look at the skeletal architecture of, let's say, bats, human forelimbs; so if you were to look at the wings of bats, compare that with our forehands or with the flipper of the whales. One thing which unites these three is the basic architecture of the skeleton, and that is unified, whether you look at the wrist architecture, the finger architecture.

Yet, you find that in bats, you have these forelimbs modified in two wings of bats, which allows the bats to flipper and fly. So, the basic origin was the same, yet the functionalities are different despite having similar architecture. Similarly, if we were to look at the DNA, as I mentioned last time also, as far as the language which quotes the information in DNA has been fairly conserved. Yet, the DNA which is found in humans is slightly different from the DNA which you find in earlier organisms, not in terms of its chemical entity, but in terms of further architectural development. So, evolution essentially talks about these changes which have been acquired by various life forces over the course of earth's history.

(Refer Slide Time: 06:30)

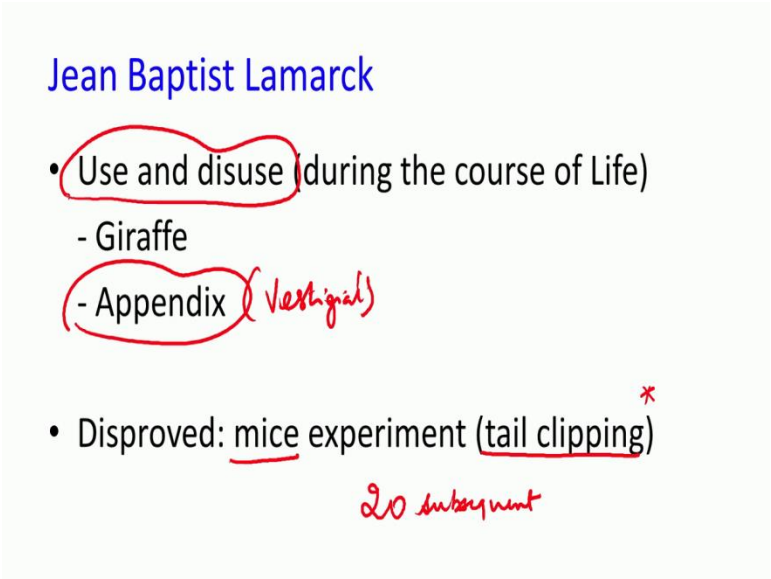



So let's look at what all is available and how many different forms of life are available on today's earth. You find that there are close to about ten to hundred million species, living species living on earth as of today, of which about two million living species have been already identified and classified. Now those of you who would have taken a classical biology class in their high school, they would have been taught that the all the living forms are classified into five major kingdoms, which is, the, bacteria, the protista, the fungi, the plant, and the animal kingdom.

But as of today, we have classified the living organisms, and this is how is normally followed these days, are into three major domains; the bacteria, the archaea and the eukarya. Now we'll come to the differences which we observe in bacteria and archaea vis-à-vis eukarya in our next class, but eukarya is the most evolved of these living entities, and it itself is divided into four different groups; the protists, this is where you'll come across an amoeba, or the hydra, then the fungi, where you come across your regular mushrooms, the plants and the animals. So, there is diversity, starting all the way from bacteria to what you see among animals, whether it is the whales, the bats, or the human beings.

There are certain things which are unifying, yet there's a huge diversity. So how do you explain this diversity, and that is essentially explained through evolution.

(Refer Slide Time: 08:40)

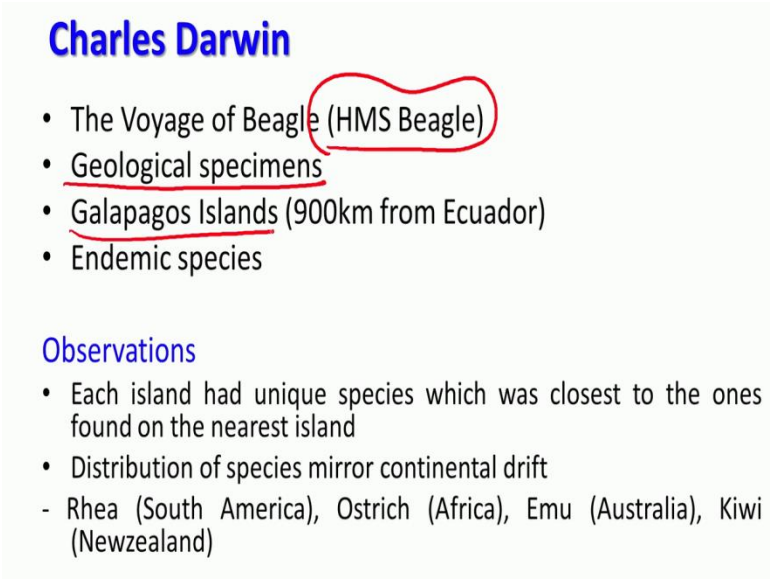



Now one of the earliest scientist who brought in the concept of evolution was Lamarck, and though his theories were disproved later, he still was one first, one of the earliest scientist to bring in that vey concept of evolution. According to him, it is the, a particular organ, or a particular feature in an organism develops during a lifetime of that organism based on the usage of that organism. According to him, if we look at the long necks of giraffe, it would have developed because the giraffe would have stretched its neck to reach to the ford at tall trees and it's constant stretching would have led to the elongation of the neck and he believed that whatever features were acquired by a giraffe in its lifetime would be passed on to his progeny.

And, he also reasoned that those organs which are not being used by the organisms will eventually become useless and that is what we call as the vestigial organs, and one of the examples is the appendix that we see in our body. But, his ideas were later disproved through multiple experiments and one classic experiment was the experiment which was done on mice, where for about twenty subsequent generations, the tail of the mice were clipped, in the hope that if the tail is being clipped every generation, and it's of no use, then, by the twenty-first generation in mice, the mice which will be born in the twenty-first generation should be without tails, but that essentially didn't happen.

So in a sense, his theory based on use or disuse of a particular part was not the reason for evolution, though he did bring in the concept of evolution during the course of life, and in the course of earth's life.

(Refer Slide Time: 10:10)



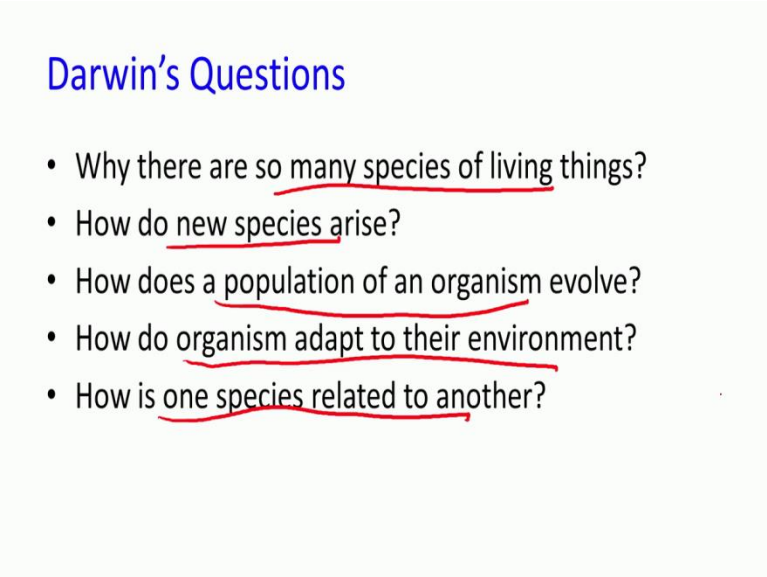

Then came the remarkable observations done by Charles Darwin. In terms of biology, even today, a lot of our discoveries, we owe it to the observations of Charles Darwin. Had it not been for Charles Darwin's observations, we would not understand the biology the way we understand it today. And, it all started with this interesting trip which Charles Darwin took on HMS Beagle. He went on a voyage along the coast of South Africa, South America through the Galapagos Islands, which are about nine hundred kilometers west of Ecuador, and then all the way to Australia and back.

He essentially joined this voyage as a geologist who wanted to collect geological specimens and study them. And in the process of studying these geological specimens, he did observe a lot of fossils of not just high end animals, but even molasses, or shelled, shelled organisms. And, the most (insta) interesting observations that he made were in the Galapagos Islands. And these are a group of islands which are spread across a few kilometers, very close to each other, but about nine hundred kilometers from Ecuador, and what we observed is that in each island, there were unique birds, species and tortoises and no two islands had the same kind of species. Yet, a bird or

a tortoise seen in one island was very similar, though not exactly the same, was very similar to the birds or the tortoises found in the nearest island.

So that was one observation that he made on the Galapagos Islands, the other observation that he made during his voyage across these coastlines of Africa, Southern America, and Australia, was that he observed that the distribution of these species was mirroring how the continental drift actually happened in the earth's history. For example, he observed that giant fly, flight-like birds, flightless birds like Rhea which is found in South America, Ostrich which is found in Africa to Emu which is found in Australia, they all look similar, and they all are flightless, yet they are so much spaced apart in terms of the geography.

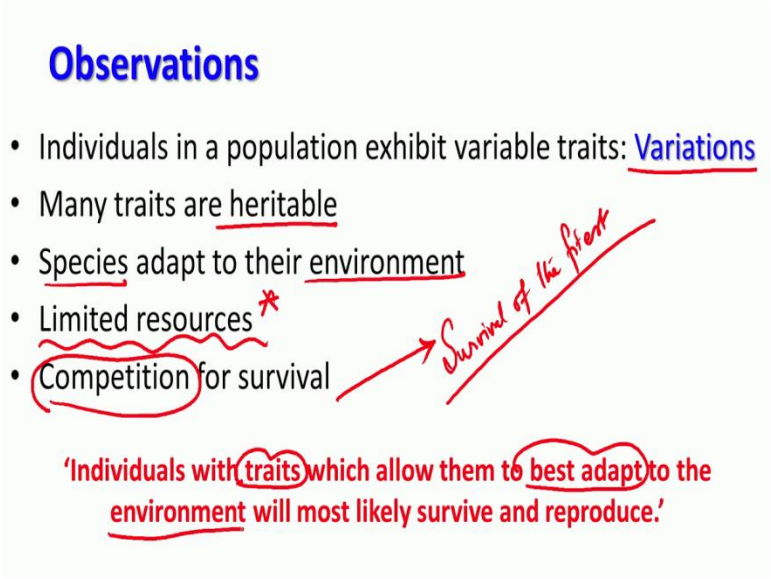
(Refer Slide Time: 12:07)




So he felt that this distribution of species has got something to do with the continental drift of the earth itself. So he asked a few questions. His first question was why there are so many species of living things, how do these new species come into existence, within a population, how does an organism evolve, and how does an organism really adapt itself to the changing environment. And how is one species actually related to another. So for example, if we look at ourselves, we would find within the population, some people are tall, some people are shorter, does it provide a survival advantage? Some people have a better muscle activity than the other, does it provide a survival advantage?

And how has these, how is it that some people are taller, while some people are shorter? And how is it, even if you look at from the evolution perspective, how is it from one generation of humans, the next generation of humans, the features are changing? Is it because it is changing because they are trying to adapt to their environment? These are the kind of questions that Darwin was asking at that point of time.

(Refer Slide Time: 14:58)

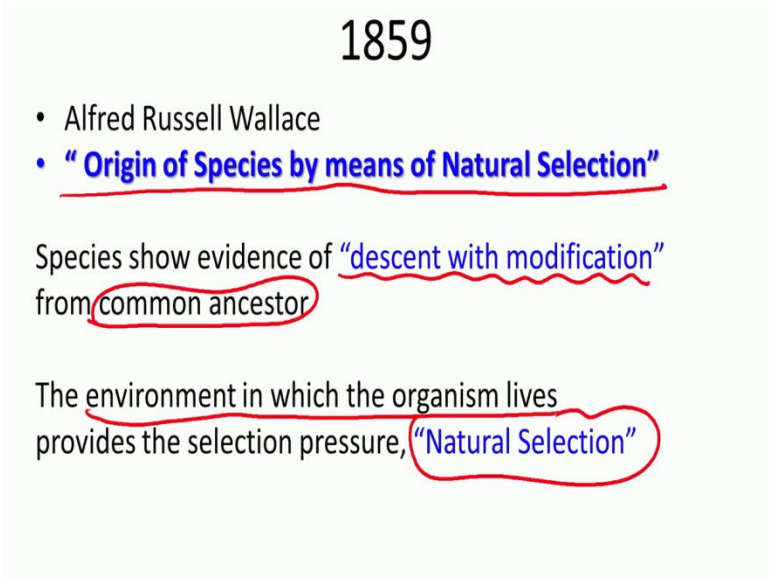



So he made a few observations. What he observed is that, in a given population itself, for a given species, so we talk about humans for example, among ourselves and in our own population, there will be individuals with different features. Somebody will be taller, somebody would have a brown hair, somebody would have a black hair, and these differences, within the same species is what you call as variations, and many of these changes are actually heritable, which means, some of these changes can be passed on from the parents to the offspring.

The other thing that he observed as he found in the Galapagos Island, is that though the species were different in different islands, based on the environment which was being provided by the island, the species could adapt to that environment. For example, in those islands where the vegetations were found at a much lower level, the neck of the tortoises were smaller, while in those islands where the vegetations were (stile) slightly at a higher level at a higher height, you found, or he found rather that the tortoises had a longer neck.

So he suggested that the species can adapt to the changing environment. The other observation that he made is that, as a population grows in size, eventually, the resources become limited. Now this is a crucial point. If the sources are going to become limited, there is going to be a time, where there will be a competition among the individuals of a population for the resource, and this is what led to what we all routinely talk about and classically called as 'The survival of the fittest'. So, with his observations, what he observed and rather postulated is that individuals with traits, or rather variations which allow them to best adapt to the environment are most likely to survive and reproduce, and not only just survive and reproduce, but pass on these favourable characters to the next generation.

(Refer Slide Time: 16:30)



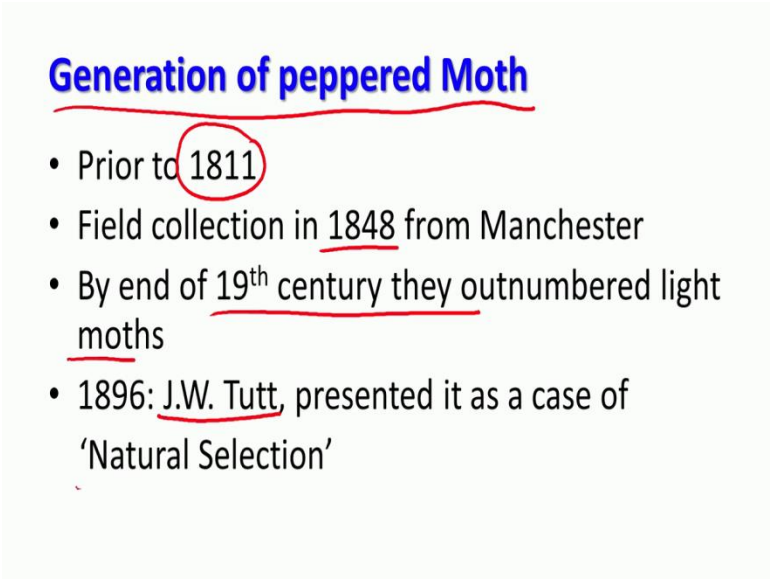

So why he was formulating all these ideas, there was another naturalist, Alfred Russell Wallace, who wrote to Darwin bit similar ideas and the two of them then decided to present their ideas to the London Philosophical Society in eighteen fifty-nine, and eventually Darwin published his most famous work, which is called as 'The origin of species by means of natural selection'. Now what does this talk about? Essentially it talks about two things. It says, any species always shows an evidence of dissent from a previous species with modifications. So, species show evidence of dissent with modification, and they all will have common ancestor.

The second he said, the pressure which brings about these modifications, or the variations, is the environment in which the organism lives. So, if the environment is changing and that changing

environment demands the organism to change, some of them, not all of them in a given population, certain individuals will adapt better because they have acquired these modifications. This pressure, which is provided by the environment is what is called as the 'natural selection'. So, in other words, let me reiterate, what Darwin said was that a species arises from a common ancestors because certain individuals in that species would have developed modifications which are favourable, which allow that organism to survive better in the changing environment, and these favourable traits get passed on to subsequent generations, allowing eventually, over a time scale of a few million years for evolution of a newer species with better characteristics.

And many a times, these species may kind of get segregated if there are continental drifts and changes happening on earth. But this was just a theory in nineteen, in eighteen fifty-nine and later on, within a very short span of about fifty years, and this has been the classic example of natural selection, has been around the time of industrial revolution, and this has been the generation of the peppered Moth.

(Refer Slide Time: 19:15)

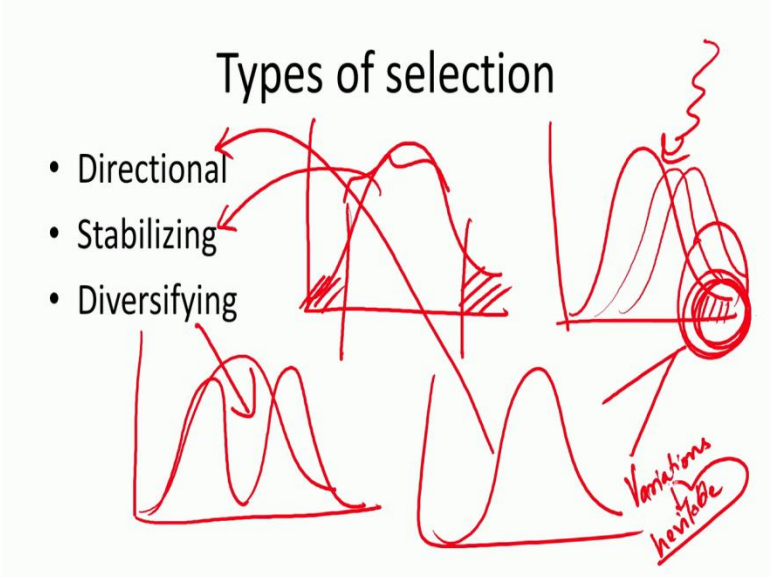



Now this was an interesting observation, which was made by J.W. Tutt and what was known then is that way back in eighteen eleven, most of the moths which were found in England , mainly in England were light colored. But a field trial, or a field collection in eighteen fourty-eight, around the time when the industrial revolution was taking place in Manchester, a lot of peppered and black coloured moths were observed, and by the end of that nineteenth century, in

a period of about ninety years, the light coloured moths was totally outnumbered by these dry, dark coloured moths. Now what could be the reason? The reason was, that during industrial revolution, because of a polluted environment, in order to survive the prey, that is the bird which will be eating on these moths, the light coloured moths will become extinct because they will become easily visible and will easily be spotted by the preying bird.

But a dark coloured moth will, being able to in the background of the suit being generated, thanks to the industrial revolution, would be able to camouflage itself to such a extent, that it will not be noticed by the predatory bird, and it would have given it a survival advantage. So this was then presented by Tutt as a case of natural selection. So here is an example where changing environmental conditions due to, in this case, human activity in industrial revolution, actually led to the generation of a peppered moth. So what are these different kinds of selections that we are talking about?

(Refer Slide Time: 22:06)



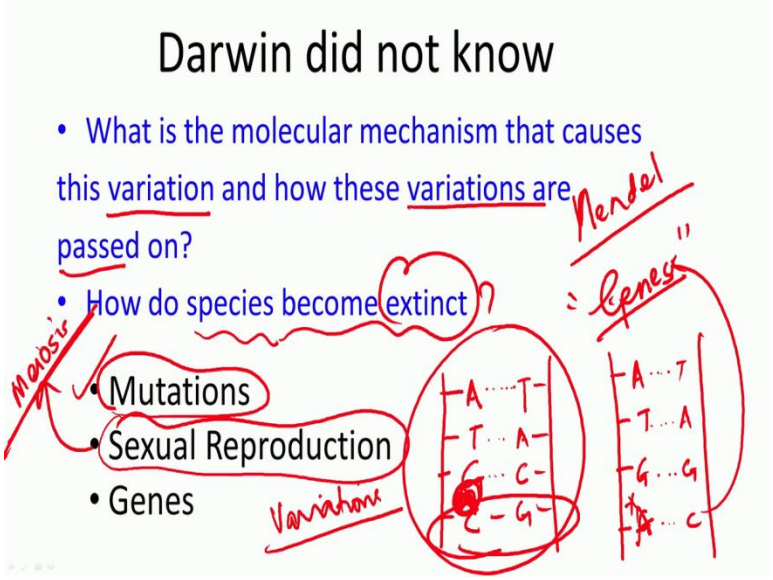

Well, as I mentioned earlier, the selection pressure is essentially provided by the environment, and how does the organism adapt to that environment. So, assume that you do have a population trait, you have a trait for which there is a normal distribution and you find that if the environment is conducive and the conditions are fine, there's no need for the outer extreme of the organisms to grow. I mean they become redundant. Now such kind of a selection where the central most acquired characters are retained is a stabilizing selection. But then, you can have a situation

where you still have a population with these kind of display where you have some extreme variations and suddenly, the environmental conditions force in such a fashion that it is this set of extreme outliers which have a survival advantage.

As a result, what'll happen in due course of time is that, this set of population will tend to move towards the favourable acquired characteristics of this set of organisms and it is this set of organisms which then eventually will form a new species. Now this is an example of directional selection. There are also examples of diversifying selection wherein you have originally your population, and then either because of a continental drift, or some other kind of catastrophe, this gets split into two populations with different characteristics and that is called as the diversifying selection.

But, thing which remains common and unifying across all this are two; one, it's the environment, which provides that pressure, the selection pressure, and two, it is the ability of a certain individuals in a given population to adapt to that change, and the reason they are able to adapt to that change is because they manage to acquire new characteristics which are favourable, and these characteristics is what you classically call as variations. If these changes are heritable, you will find that over successive generations, the (variation), this originally acquired (vari) variation which eventually become a characteristic of that particular group of organisms.

(Refer Slide Time: 26:05)



But, Darwin did not know certain things. He did not know what is the molecular mechanism which actually causes this variation. He knew that the changes are happening, but what is causing it? What is the molecular mechanism which is causing these variations? And how are these variations are being passed on? And this is where the role of Mendelism and Mendel's genetics becomes very important, which will be covered by my colleague, Professor G.K. Suraishkumar. And this is where the role of genes, each gene in our DNA codes for a certain character. It is the genes which carry these variations, but, what is it and how are these variations introduced into these genes? We'll talk about that a little later from now.

But, Darwin did not know the mechanism. He also did not understand why certain species for which he had collected the fossil samples become extinct. What is the cause of extinction? For example, for dinosaurs, and answer was not available then. So how are these variations caused? There are multiple ways, and the most classic way is the process of mutation. Now, we all know that our genetic material is encoded in DNA, so let me just draw a strand of DNA with a certain sequence. So the complimentary strand, we'll cover this again when we talk about DNA replication, but for the simplicity sake, each strand of DNA mirrors it through a complimentary strand. Right?

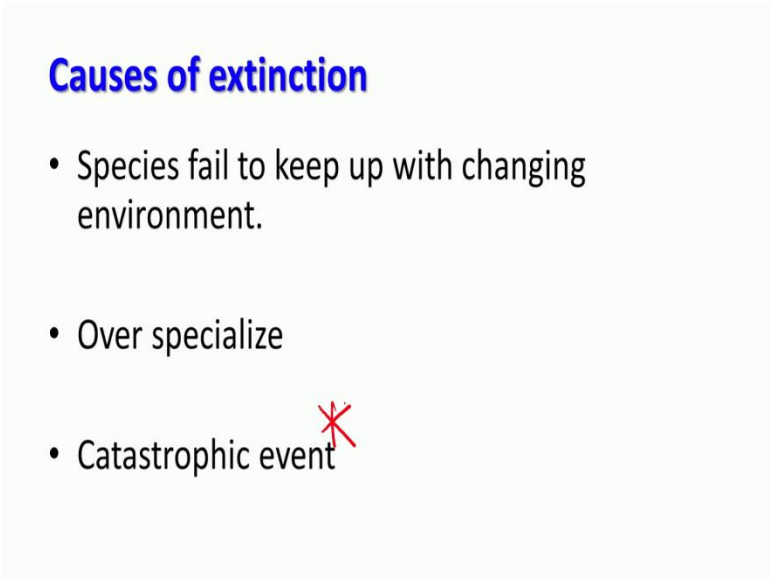
This is a DNA. Now, if this molecule of DNA were to undergo replication, and for some strange reason, there error happens because of which the sequence in the DNA, let's say, changes, and the errors are a part of life, I mean they do happen pretty common, and now, you'll have a new DNA molecule which has a mutation where this C has now been replaced by a G, or a let's say an A. So now, this mutation has happened and if this mutation is going to impart a favourable character to the gene in which it is present, then this becomes a favourable variation. So mutation, or changes in DNA sequences which are heritable and which do provide favourable effect on to survival could be one of the reasons by which the variations are happening.

The other reason for the variations has been the process of sexual (reprodution) reproduction. We all know that we get a certain set of genes from our father, and a certain set of genes from our mother, and we are neither a carbon copy of our father nor our mother, we have a mix features because some genes have come from our father, some genes have come from our mother, and as a sum total and a combined effect. Now this has been one of the major reasons for variation and is one of the major reasons for success of survival in higher organisms.

Now how are these variations through sexual reproduction brought about? What is the process? We'll discuss this variation, and even in this variation, how are these variations brought about? We'll discuss them when we are talking about the process of 'Meiosis', and I'll come to that when I'm talking about meiosis. So, there are ways by which across evolution, over a period of billions of years, the DNA has evolved, and it keeps evolving, sensing (chan) demands of the environment, and these favourable changes have went on accumulating and over a long period of time, a point will come when the original species will end up giving rise to a newer species.

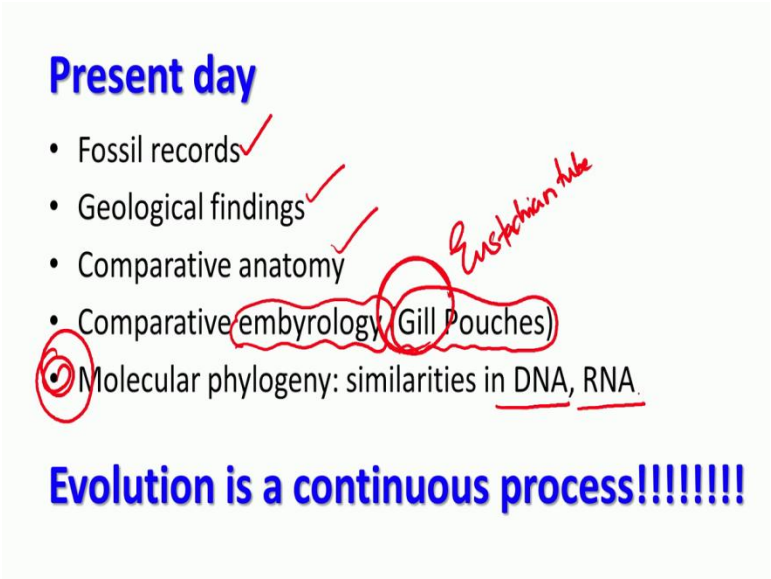
And what are the causes of extinction? Well, a lot of these are speculations because we cannot go back in history and try to redo what has been done, and we can't recreate a lot of environmental changes which must have happened a few billion years ago. But, we speculate that if a species fails to adapt itself to a changing environment, it's going to become extinct, or if it specializes to such a point that it cannot readapt itself, then also it can undergo a cause of extinction.

(Refer Slide Time: 26:51)




And then the classic example has been the disappearance of dinosaurs because of catastrophic events. So, there are ways by which life evolves, and then it not just evolves, it keeps on accumulating these changes and most of these changes which have managed to survive across evolution have been those changes, which have given a survival advantage to a given organism, and as a result the organism tries to retain it and the life tries to retain it for further passing it on to the progeny.

(Refer Slide Time: 29:20)




So in present day, we tried to understand revolution through fossil records, through geological excavations; we also tried to understand how the organisms would have evolved by comparing the anatomical structures, as I mentioned, in case of skeletal formation or comparative embryology. Now this is an interesting observation. For example, if you were to look at the embryonic development of fishes or reptiles, birds, all the way upto mammals, we find that the embryonic stages, all of them, right from fishes till humans express at a certain stage in their embryonic development, a structure called as the gill pouch, which is around this area.

But, in case of fishes, the gill pouch actually evolves and forms the functional gills through which the fish respires. Well in humans, though it is present in the embryonic stage, it later ends up becoming a 'Eustachian Tube', tube or a tube which actually connects your middle ear to the nose. To the throat, sorry. So, basically, what you find is that these gill pouches are present during the embryonic development all across from fish to the humans.

So you can do comparative embryology and try it group and see how evolution must have taken place, and the most recent is the advancements in molecular biology techniques wherein we are looking at the similarities in structure, the sequences of DNA and RNA, and are linking it to the process of evolution. For example, the DNA which will code for enzymes, for basic metabolic reactions are highly similar across evolution. Yet, in some organisms, it's a little more better

evolved than the lower organisms. So by comparing the actual DNA and RNA sequences, we can also estimate how closely the species are inter-related, or they have diversified.

So, there are ways to understand this evolutionary process. So I would like to again, end this, or rather sarize this talk by saying that evolution is a continuous process. For all you may know, as we are talking and as are our cells dividing, if mutations are taking place with time, and if these mutations accumulate and become favourable, it becomes a variation. So it is a continuous process. However, the end results of these evolutions are not going to be seen in our own lifetimes, but probably in millions of years down the line.

So, I would like to again say, that the crucial part in evolution has been the theory of Darwin, which is the 'Origin of Species by means of Natural Selection', where the natural selection is essentially provided by the environmental changes; and in order to adapt to the environmental changes, individuals in a population will develop variations. And these variations may either happen because of sexual reproduction, because of mutations and if the variations are favourable, it'll keep on getting accumulated over successive generations, unlike Lamarck's theory where he was only talking about doing the lifetime of a individual organism.

Darwin extended and he explains that these evolutionary changes accumulate over generations and then diversify into a newer species. So with that, we have talked about evolution, and if you are interested to read more and get a better perspective on how it actually happened? What was the voyage of Beagle which was taken by Darwin, I would recommend that you take your time out and go through some of these videos on Youtube. Thank you and see you later.

(Refer Slide Time: 31:54)