Introduction to Evolutionary Dynamics
Prof. Supreeth Saini
Department of Chemical Engineering
Indian Institute of Technology, Bombay

Lecture – 01
History of the theory of Natural Selection – 1

Hi, and welcome everyone to the course Evolutionary Dynamics. My name is Supreet Saini, and I work in the Chemical Engineering department at IIT, Bombay- Indian Institute of Technology Bombay in Mumbai. And through this course evolutionary dynamics I mean evolution is a subject which she has interested people for a very long time, but what we want to do through the medium of this course. In the next 20 hours or so for which I will be giving lectures what we want to do is provide discuss tools which can be used to give a quantitative framework associated with evolution. If you are interested in understanding evolution and the statistics and its dynamics associated with it what would be some of the tools that would be required to analyse this and in this sense this is going to be a mathematical courses in some sense at least at some level.

However, the way I will be discussing aspects associated with this course, this course is sort of ideal for biology or students of biology who are interested in learning about mathematical tools which people use to understand topics associated with evolution. I will be taking things very slowly when it comes to mathematics and often repeat myself, so that any biologist, who has some interest in learning about the mathematics associated with biological processes, is able to keep up with the speed at which we will be discussing things and also understand the mathematics behind the development of these frameworks.

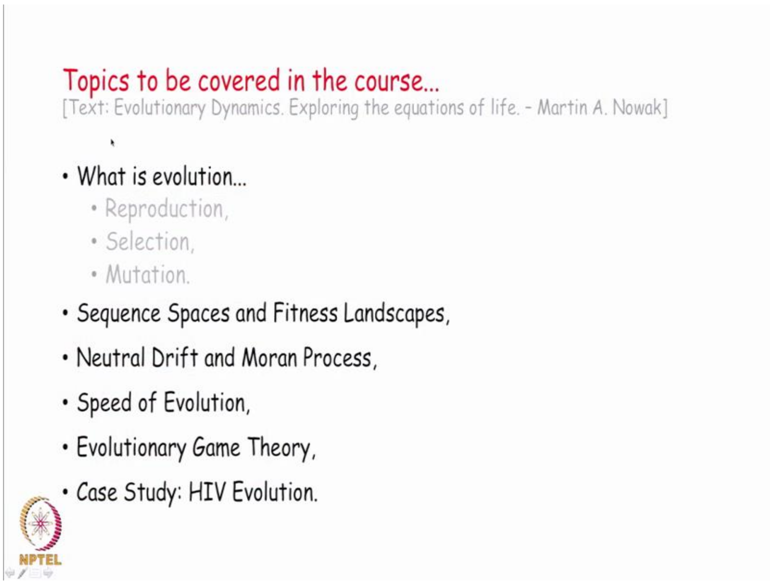
On the other hand for anybody who is coming from physical sciences and is understand is a interested in understanding biological processes, and how can he or she combine their quantitative skills that they have learnt as part of their engineering or physics or computer science or any other background that you are coming from into biological processes and specifically processes associated with the evolutionary dynamics they will find this course of use.

Evolution can be understood at many many levels, but what we will be discussing in this course will primarily be restricting ourselves to prokaryotes which are single celled organisms essentially bacteria is what we will be talking about. Quantitative theories of evolution are very hard to develop, evolution is a is in some sense random process where mutations occur randomly throughout the genome of the organism in the DNA associated in the DNA sequence associated with any bacteria and these mutations enable the enable a particular individual which has acquired them to perform task which are perhaps in a which are perhaps better than what others in the population can, enhance that leads to a competition between individuals in a species we are only ones which are the more which are the fittest are able to survive and the rest are eliminated from the population because of this inherent because of this inherent competition between individuals.

So, because of the nature of mutations which dictate this dynamics of competition and elimination and survival in an environment, because this nature associated with mutations is random in nature evolution in many senses is a statistical problem. And in order to get any meaningful insights into this process you have to understand the probabilities associated with different processes which might happen in a evolutionary outcome; because really if I do an evolutionary experiment in lab. Every single time when I do that experiment I am going to I am likely to see a different outcomes in terms of how that organism adapts via sequence mutation in coping up with a stress that I am giving it in a particular environment.

So, in that sense that is the evolution is a statistical problem and some quantitative understanding of probability and statistics is required to be able to understand these topics. This is a relatively short course of about 20 hours of instruction. So, we will know when near be able to cover all aspects of quantitative revolutionary dynamics that we might want to, but here is a quick glance into what all will be covering in the next 20 hours or so.

(Refer Slide Time: 04:41)



So, of course, the course title is evolutionary dynamics and the text that will be following is called evolutionary dynamics exploring the equations of life this is a text by the author Martin Novak and this is a very very nicely and easy to understand written book, and the math should not intermediate you at all and we will be closely following topics which are developed in this book. In a way of how we plan to cover this course we will start with what is evolution. Evolution is essentially three processes coming together reproduction selection and mutation and all three operating together lead to a species evolving.

We will start by development of equations that combine that allow us to understand each of these three processes in a mathematical framework, and again I do not want the biologists to get scared the development of these equations and the mathematical processes throughout the course of these 20 hours will be very slow, and I am hope you will be able to follow those mathematical steps with me. From development of equations related to these species we will come to something called sequence spaces and fitness landscapes structure which are important to understand when you are trying to understand how population might adapt in an environment. And specially understand the randomness associated with evolutionary processes as to what might be the variation in the outcome if you were to perform a single revolutionary experiment many different times.

So, sequence spaces and fitness landscapes are a very important tool which helps you understand that particular aspect associated with revolutionary dynamics. Now from there we will come to this third bullet which is called neutral drift and Moran process; neutral drift is a process where randomness associated with populations drive evolution, there is no selection process there is no individual which is fitter than the others present in the population everybody is equally fit or equally unfit, but just randomness associated with the evolutionary processes drives evolution and that process is called neutral drift.

And Moran process is one way to quantitatively understand and model evolution via neutral drift which is happening. So, we will develop that after that we will spend some time on the forth bullet which is called speed of evolution, and what we will be talking about there is that in the context of a microbial population can we come up with analytical frameworks and can a can we develop expressions which help us quantify speed of evolution associated with a microbial population or an experiment.

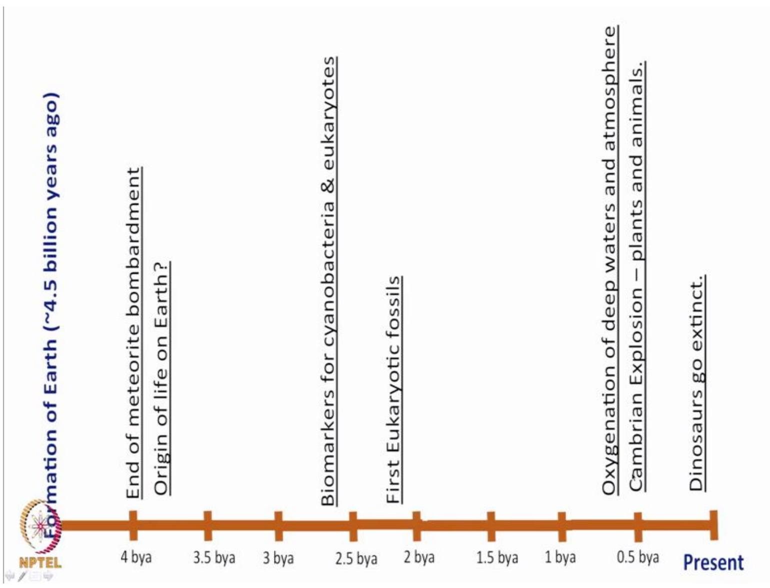
By speed of evolution what we mean to say is that how quickly does the growth rate associated with the species change with time when the grown in an environment, which we define and control through the course of the experiment. Again I think this is the very useful exercise to be developing expressions like these and they give us a framework in which to pose our experiments and understand which parameters what kind of a role in dictating dynamics associated with these equations.

We will end the course by a discussion on evolutionary game theory, and there is a large amount of literature which uses game theoretic approaches to understand evolution, where two strategies or two genotypes are being competed against each other and people try to analyse as to whether a new strategy arising in an environment such as this will help displace the existing strategies and take over. And this and then the concept of strategies from game theory can be easily extended to genotypes associated with or DNA sequences associated with living organisms and what we are trying to understand there is that is one DNA sequence able to is an individual with one particular DNA sequence able to eliminate individuals with other sequences. And this has important implications in terms of what will comes into play here is variables like randomness associated with this process, sometimes individuals who are doing better than the others are not able to out compete others. Variables like population size what was the size of the population in which this experiment was being done dictate the dynamics associated with this process.

So, we will spend some time on evolutionary game theory and we will close the course with a case study in which we discuss a particular case which is how does the virus HIV which causes aids in human beings able to compete with the immune system and how the interplay between these two the immune system on one hand and the virus on the other hand, how the interplay between the two dictates the dynamics of viral progression inside the host.

So, that is abroad overview of what we propose to cover in the next 20 hours or so, but for the first few bits of the course what I want you to; what I want to do is take you through the journey which is associated with development of theory of natural selection. So, we will spend some time doing that and then and once that introduction of theory of natural selection is done what we will start is start with the development with the first bullet point which is development of equations for the three processes inherent to evolution which is reproduction selection and mutation.

(Refer Slide Time: 10:13)



So let us start our discussion and this a brief time line of the processes on earth. So, the x axis here is time and the rightmost end point of that line dictates represents the present. Each of these bars here represent a time of 500 million years or half a billion years. So, if we go all the way back to the left of this line, we get formation of earth happening 4.5 billion years ago. This is just to get an estimate of how long has the process of life been going on our planet. So, 4.5 billion years ago earth matter condensed and earth was formed, around 4 billion years ago we get end of meteorite bombardment on earth more or less stabilized after that.

The first indirect living evidence that we have of life on earth comes from some samples which are collected in green land and that gives us a clue as to life may have originated on earth as far back as about 3.85 billion years ago on earth, which is a really really long time. And then once life originated and archaea and bacteria are thought to be the first life forms that originated on earth, and then for a very long time nothing changed and it was only these species which existed, multicellular organisms came into picture way after that. And the way multicellularities or eukaryotes have are thought to originate is that somewhere along the line and an engulfment event happened where an archaea engulf the bacteria, and that bacteria was now which is living inside the archaea now developed into what we call today as mitochondria, these mitochondria act as powerhouses of the cell.

And what this engulfment event enabled is that it by orders of magnitude it increases the amount of energy that was available to each cell. And because the amount of energy that was available to each cell increase significantly after the engulfment of bacteria and those bacteria then developing into mitochondria inside the cell, the ability the number of tasks that a single cell could perform. Now increase significantly and hence that process lead to development of all the complexities like development of a nucleus, development of act of transport systems inside the cell, development of sex all those things happened once that engulfment of bacteria happened and those bacteria then became what we call today as mitochondria.

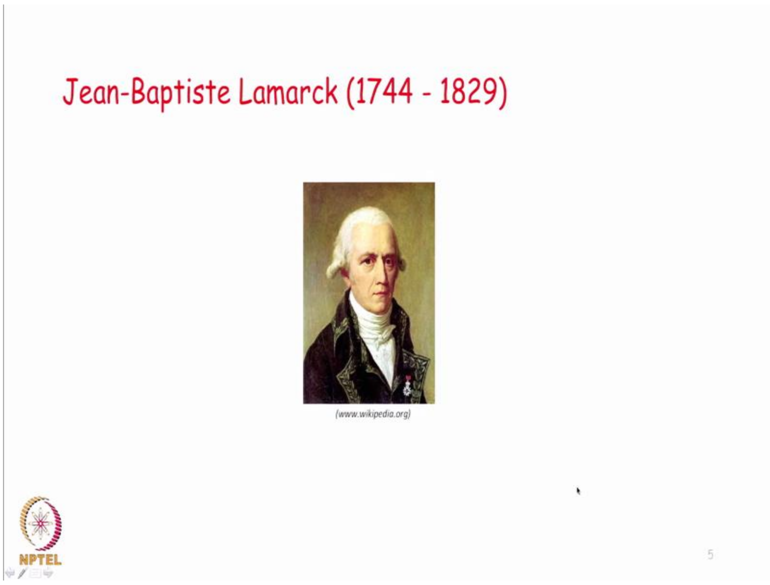
And this if you look at the chart here represents the first evidence for this is about 2.7 billionaires back when we where we have some bio markers or cyanobacteria and Eukaryotes. The first real evidence for presence of Eukaryotic fossils only happened only comes from about 2.1 to 2.2 billion years back where you have the first fossil records of eukaryotes on earth. And then for the next billion years or so, or a little more than a billion years or so, we do not believe that there was much evolution in terms of complexity of organisms took place and what really dictated the next phase of evolution was oxygenation of the atmosphere and oxygenation of the deep ocean.

These environments did not have oxygen earlier on, but with the spread of cyanobacteria which perform photosynthesis, oxygen was released in massive amounts and the oxygen levels are thought to at one point speculated that it crossed 30 percent as much as 35 the oxygen levels went up to as much as 35 percent in the atmosphere and that really enabled life to flourish, and that that oxygenation event if we go back to our graph. Now we can see that this is this enable the Cambrian explosion where plants and animals really came into being and this process is said to have started a little over half a billionaire years ago.

About the 65 million years ago when dinosaurs are thought to have gone extinct and its only in the last instant of life associated with earth if we are looking in the scale as we are in the figure that human beings enters the picture and life as we know it came to be recognised and classified in the very recent future of earth; that is a brief history of our planet earth what we want you to do today is talk about the story associated with theory of natural selection.

So, if we go back to beginning of 19th century on earth and if we go back to Europe Western; Europe where industrial revolution has taken place and if we ask somebody the following questions that where did species come from? If we ask somebody that question the most popular and the most accepted answer associated with this question is going to be that species were created by god and they were immutable, species as we see them today in the early 19th century that is have always existed in the fashion that we see them and they are immutable they do not change over time. So, that was the prevailing view and anybody challenging that view was a in direct contrast with views of the church and hence it this was a belief that was formerly helded in the society at that time.

(Refer Slide Time: 15:54)



And the first person to challenge that view was somebody called Jean Baptiste Lamarck. I am sure many of you would have heard of it, in 1809 he was a French naturalist and in 1809 provided the first comprehensive theory associated with evolution of species; where he was the first person to provide a comprehensive framework in which he proposes that species are not immutable species change over time.

And the theory that Lamarck provided was the theory of use and disuse. And the argument was that if I has a entity am using one particular organ of my body more extensively then the other organs of my body, then in my progeny will have that particular organ as more developed as one of the examples that is common in textbooks is that if you are using your right hand to constantly hammer objects, then your arms around the shoulder and of the right arm are likely to be more developed than the others. And as a result your progeny will have these muscles which are well developed as compared to the ones on the left for instance.

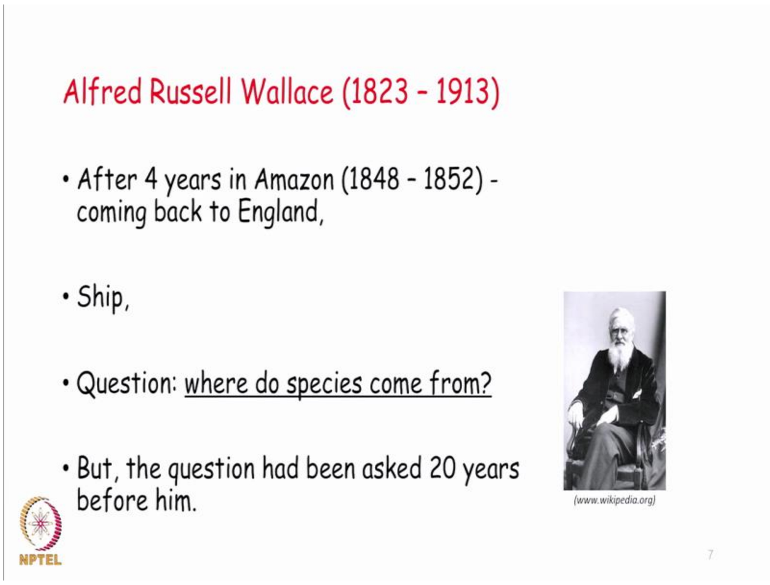
So, this was Lamarck's theory of use and disuse Lamarck was wrong that is not how species change from generation to generation, we are really the significance of Lamarck's theory lies is in the fact that he was the first person to challenge the prevailing view of the time that is species are immutable and come up with the first concerted theory of evolution and this was done in 1809.

1809 was also the year when Charles Darwin was born who I am sure everybody knows, but to understand the theory of evolution we will be talking about three people in particular.

(Refer Slide Time: 17:43)

And those three people are as listed here Alfred Russell Wallace, and Henry Bates and Charles Darwin. All three were British naturalists they were interested in life and it was curious set of incidents starting from 1820 onwards lead to development of theory of evolution. We will discuss them one by one and I want to talk about the story associated with these three people because I think it is really interesting. To understand this let us start with Wallace.

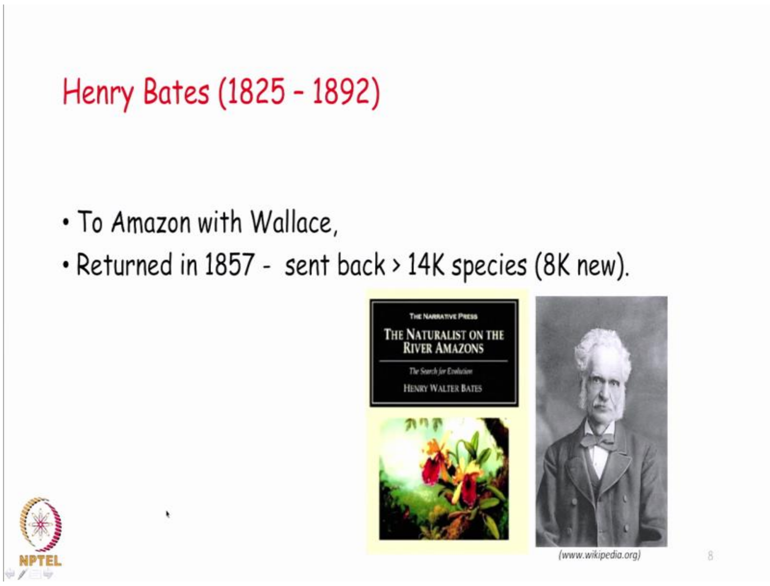
(Refer Slide Time: 18:09)



Wallace was coming back had just spent four years in Amazon he was collecting samples in the rain forest in Argentina; and in 1852 he was coming back to England he was crossing the at pacific ocean with samples. Scientists of the 19th century often came from very rich families and Wallace was an exception Wallace did not really come from a rich family and he wanted to make money by selling his collection to museums to private collectors and so forth. And when the ship is in the middle of the Atlantic Ocean his ship catches fire; he loses all his notes, he barely survives and makes it to the lifeboat and along with his notes and written documents and everything all the samples that he was bringing back to England are lost.

Wallace is devastated because he spent 4 years of his life in the Amazon collecting samples. And the question that he that propelled him to go to Amazon and collect samples extensively was the following which is given on the slide here he was interested in the question that where do species come from, where did a specie like man or a monkey or anything like that where did this specie come from how did it come into being. Of course, Wallace had no idea that 1852 when he was trying to answer this question, this question had be had already been asked and answered almost 20 years back that person I am sure all of you remember is Charles Darwin; that was Wallace's story lost all samples barely survived he was rescued from his life boat by a ship which was passing by in the Atlantic after spending eleven days on life boat.

(Refer Slide Time: 20:02)



That brings us to the next person that we want to talk about which is Henry Bates. Henry Bates went with Wallace to the Amazon; both of them spend 4 years there together and after 4 years of collecting samples Wallace wanted to come back to England, Bates stayed back in the Amazon collecting samples. Eventually bates returned in 1857 after having spent almost like 10 years abroad in South America, and through these 10 years he sent back more than 14000 species and his most popular book is called the naturalist on the river Amazons and of the 14000 species that he had spent 8000 species were never known before and he was the first one to characterize them.

So, Bates and Wallace parted ways in Amazon, they went their separate ways collected samples Wallace came back Bates stayed stayed back Wallace's ship catches fire and he is eventually rescued and comes back to England empty handed and having lost a lot of money. So, this was the story of these two men and we will come back to Bates and Wallace, but first we want to go back and talk about the third person associated in the list of characters in the list we are interested in which is Darwin which is something, that we will continue in the next lecture.

Thank you.