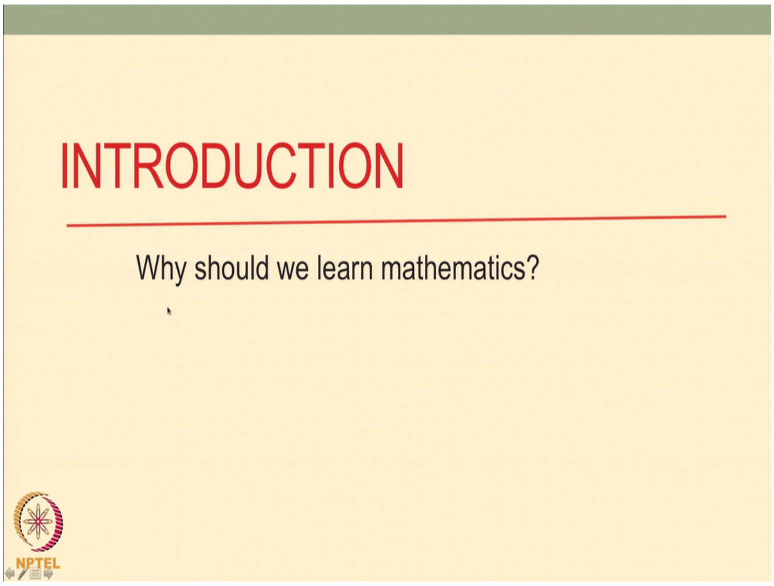
Introductory Mathematical Methods for Biologists
Prof. Ranjith Padinhateeri
Department of Biosciences & Bioengineering
Indian Institute of Technology, Bombay

Lecture – 1
Introduction

Hi, welcome to this course, Introductory Mathematical Methods for Biologists. As the course name suggests, this is a course which would introduce you to some mathematical methods which will be very useful for doing biology.

(Refer Slide Time: 00:42)



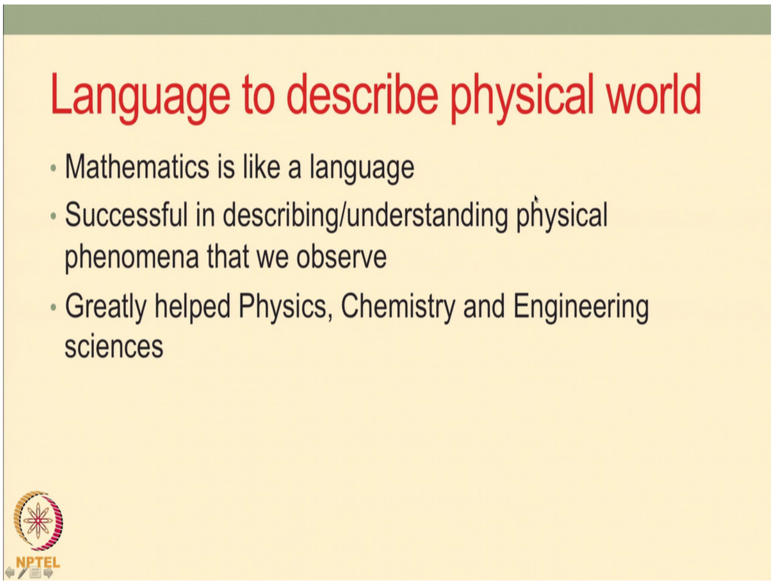
In this first lecture, which has titled as INTRODUCTION. So, the first lecture is of course, introduction to the course, where we will little bit describe about this course and we should also answer this following question, why should we learn mathematics? So, this is the question that you would try to answer in this lecture. Why should we learn mathematics?

So first of all, this course is Introductory. It is not a course for understanding detail, model mathematical modeling which is not an advanced course. This is a course mainly meant for students who do not have mathematical training at the undergraduate level, many of the biology students who do not have any mathematical training after school. So, if you are a UG student, biology student, this could be for you. Or if you are a postgraduate biology student who did not have any mathematical training after school, this is indeed for you.

If you are doing PhD in biology, and you would want to know some mathematical concepts which is important this is also for you. So, the aim of this course is to help biology students to learn Introductory Mathematics which conventionally is not taught in universities and the undergraduate level is the BSc, Bachelor of Science, live sciences subjects typically Maths is not taught conventionally. So, this is to help those students who has not had, who did not have mathematics. Also, students who take biology as like BTech biotechnology, those students also would want to know mathematics and understand those concepts. So this is also for such students. We will see what we will learn in this course.

So, first let us think about; why should we learn mathematics at all; like if conventionally, it is not taught why suddenly why should one learn mathematics. So, let us that is what you would answer first you try to answer.

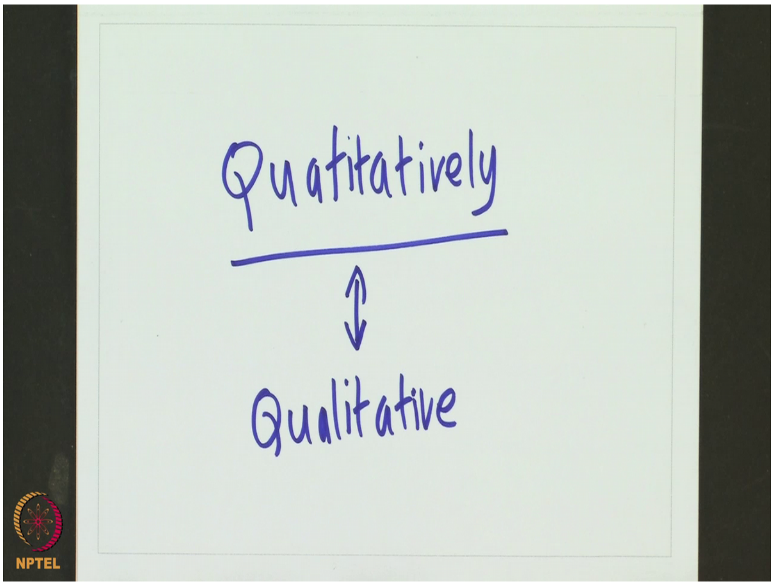
(Refer Slide Time: 02:50)



So, let us go through this point. So, the important point is mathematics is not like a specialist. We are not going to deal mathematics as a separate specialized topic; we would rather use mathematics as a tool to describe the world around us. As in mathematics has been used as a language, as a tool, as a subject essentially to describe the physical world around us; like whatever we see around us. Of course, you know that in other subject like physics, chemistry, engineering etcetera those are subjects which they study the physical world around us and they are also the subjects that study physical world around us and they use mathematics to describe the phenomena typically that we see around us and you get a training, you get some special training, how to use mathematics to describe the phenomena around us.

Now, why mathematics? Because, mathematics is like a language just like we would use English or any other language. For communicating things that we see, mathematics is a language for scientific communication to precisely and quantitatively say things.

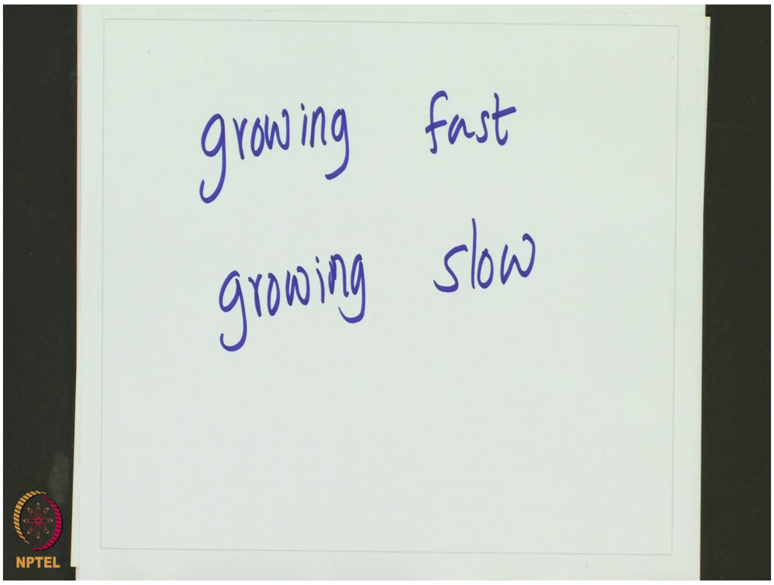
(Refer Slide Time: 04:12)



So, this is the keyword that all of would you would want to remember. If you want to quantitatively as opposed to qualitatively. So quantitatively, quantitative is the word as opposed to qualitative. So, this is the.

So, one could say things qualitatively using English or any other language we are going to describe. If it is descriptive, one could just describe qualitatively using the language of our choice like typically let us say English. For example, like a typical phenomena that we would see in biology is growth. So, using English we could say something is growing very fast or very slow, right?

(Refer Slide Time: 05:08)



You would say, so you have a bacterial colony or a particular colony growing fast, growing slow. These are some statements that we can make using English, but fast, slow etcetera are relatively qualitative description.

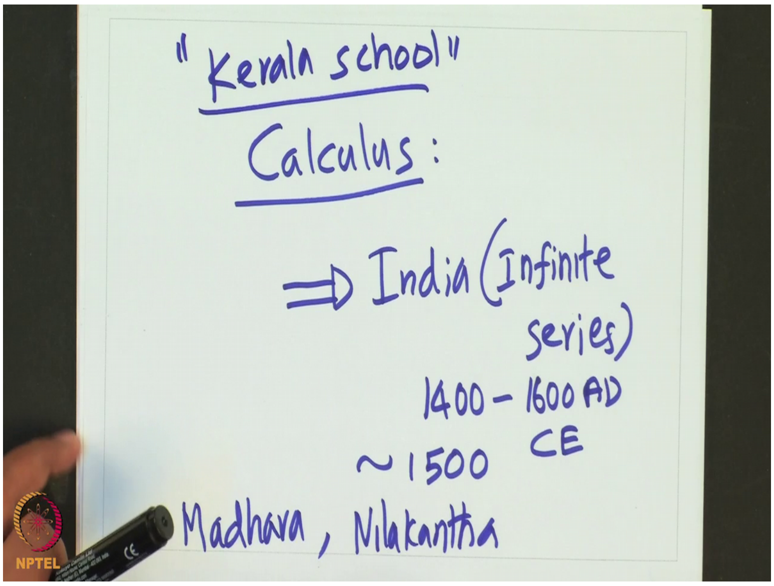
But can we quantify? How fast is fast; how slow is slow; compared to what, is there a quantification of slow growth versus fast growth. This quantification is possible using mathematics. So, this is one example. There are many other example where we would observe things around us and we could quantify precisely, make precise, accurate statements and mathematics is a tool to this. And this is 1 reason why we should use mathematics. And this is important to remember just we said, mathematics is successful in describing and understanding the physical phenomena that we observe, observe various physical phenomena that we observe.

So, starting like many 100 years, when people started thinking about planetary motion or people start thinking about motion of any particle even a stone or even a apple or anything that is falling down moving. So, whenever we started observing motion which is the things that we would see around us, people started developing some kind of mathematics to describe it which later known as calculus like many people contributed it. In the way we teach today, lot of contribution by Newton, Lebanese, they all used and developed ideas of calculus. Even though they had some origins in India like early a 1400 and 1500 AD Indians observing planetary motion had some thought on infinite series etcetera which you will see in this course where, they independently thought of some tools of mathematics which would be useful in describing some things that we have they observed. Later independently, in probably independently in Europe, a 200 years later around 1600 and 1700, people started developing calculus which became a revolution in itself and which changed physics as a subject completely.

So, that revolutionized physics, this understanding of calculus and that could that was that was successful in describing many phenomena that around us accurately, qualitatively, precisely and all that. And that changed the way we do a physical sciences itself which helped not only physics, but engineering, math, chemistry and many other subjects. And so that is the, that is the first thing. So, just to remind you some history of mathematics of course, it has very long history. We wouldn't go to the very old history of mathematics of course, from Before Common Era, BCE. Of course, the history of mathematics started with numbers and so on and so forth.

But, something which apart from the knowledge of numbers etcetera, in recent phenomena something that revolutionized our understanding is this thing called Calculus.

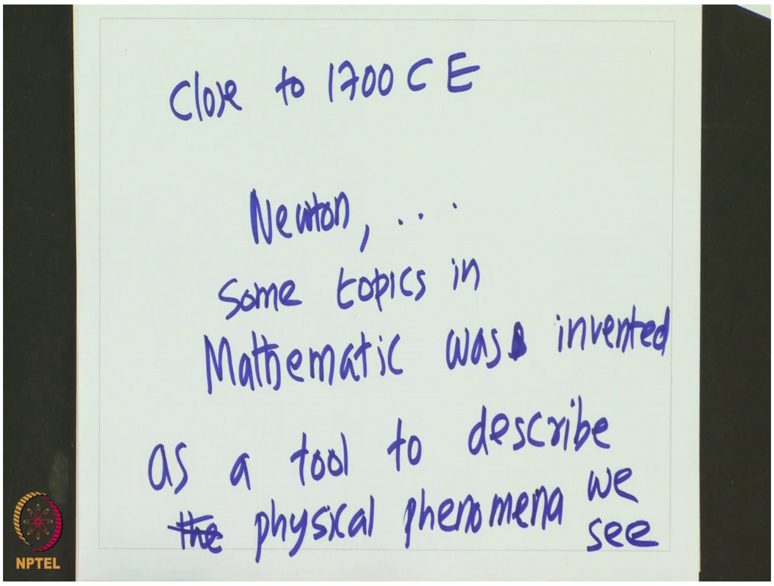
(Refer Slide Time: 08:50)



This has some early knowledge in India. Some part of some form of introductory form of calculus in the in infinite series. This is the very beginning of calculus. This was 1400 to 1600; around 1500 AD that is or CE it is called Common Era.

So, this is around 1500 the Common Era. So, around some around, this period by many people like Madhava, you should read about this. And this is known as Kerala School of mathematics. You should google search and learn about which now known as Kerala school of astronomy and mathematics. We will talk about this a little bit later, but that is why beginning of calculus in some sense. And later, it became really it really, the way we know it was developed by Newton and Lebanese.

(Refer Slide Time: 10:21)



In the 17 century, solely of course, close to 1700 Common Era which is AD. People like Newton, Lebanese and all that and many others use this to describe, Newton particularly used to describe motion like gravity motion.

So, that changed a lot of things. And that revolutionize things and that helped us. So, they are, they have to invent Mathematics some, they have to invent many new things. So, Mathematics was used was invent, some many, some branches of mathematics was invented. Some branches, some topics I would say in mathematics was invented as a tool to describe the physical phenomena that we observe. Or various physical phenomena that we see around us; like just like motion of planets or falling of an apple or you could think of motion as simplest example.

So, that changed and that could that give us a lot of very interesting insights and changed a lot of things. And later of course, the probability theory in mathematics was heavily used. In many branches like including quantum physics and the statistical thermodynamics and so on and so forth. That also helped a lot in thermodynamics in particular to change a lot of things that we otherwise we didn't know was heavily used to understand many thing, new things about thermodynamics; the things the world around us. And it also helped chemistry the quantum revolution, helped chemistry in particular that also helped us the microscopic world around us. And then came an era where people are interested to understand the living world which is the life, which is of our interest. And to understand the science behind the life; how the cell functions and how things function, of course, mathematics was used in genetics. Many mathematicians and statisticians contributed immensely to genetics.

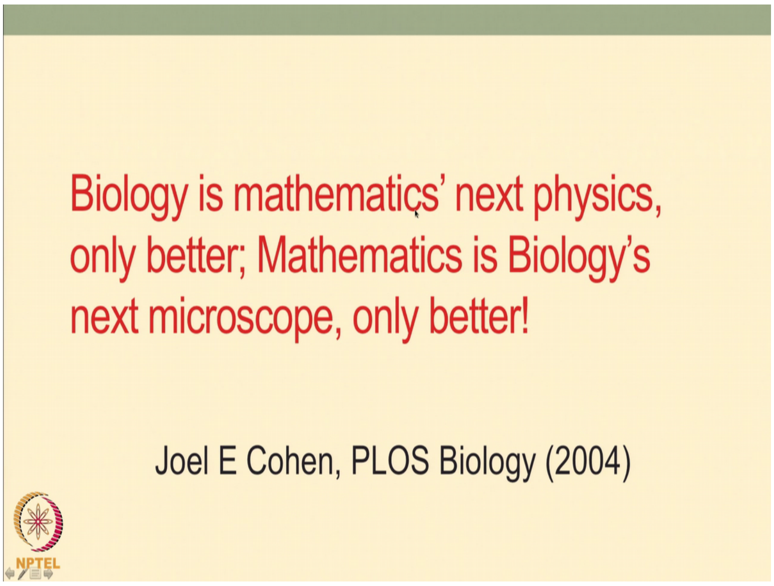
So, it helps in many ways. So, it greatly helped physics, chemistry and engineering sciences of course, which is a well known thing to everybody. But it also helped biology itself. You would know, many of the famous people who contributed to genetics are mathematicians, statisticians. And in the post 1950's, as we have more and more, as the biology kind of exploded, after the discovery of DNA structure and many things. And as we have more and more tools to probe experimentally, lot of revolution happened in biology and lot of new things started emerging.

And in understanding the things, that are going on inside the cells, a language that we use to describe other things in the nature. For example, the physical world around us which is, which we would call as the dead things like the stone or whatever we would see around us which is not living, which is dead, we use mathematics and it was the highly successful. So, the question is could we extend it, could we use it now to understand the living world as well. Of course, that is the most obvious candidate it should we would not need to use mathematics to make sense and to quantitatively explain, to understand the phenomena in the living world.

And therefore, it is important to learn mathematics, to describe the living world just like we have been describing physical world, physics, chemistry and engineering sciences. Biology is a science where we see things the living world, but that is also a physical natural world around us and mathematics is a natural candidate as the language to describe the phenomena, that to describe the phenomena quantitatively, scientifically.

So, that is the language that one should learn. Interestingly, there is a very famous mathematical biologist made a very interesting statement in article in which published in PLOS a journal called PLOS Biology.

(Refer Slide Time: 15:25)



And let us read out this journal. The statement, the statement is very interesting. The statement is, Biology is mathematics' apostrophe here, note the apostrophe; here this is of mathematics' next physics, only better; Mathematics is Biology's next microscope, only better! So, let us understand these 2 parts. The statement has 2 parts, understand this parts whether it will help us to understand why this statement was made.

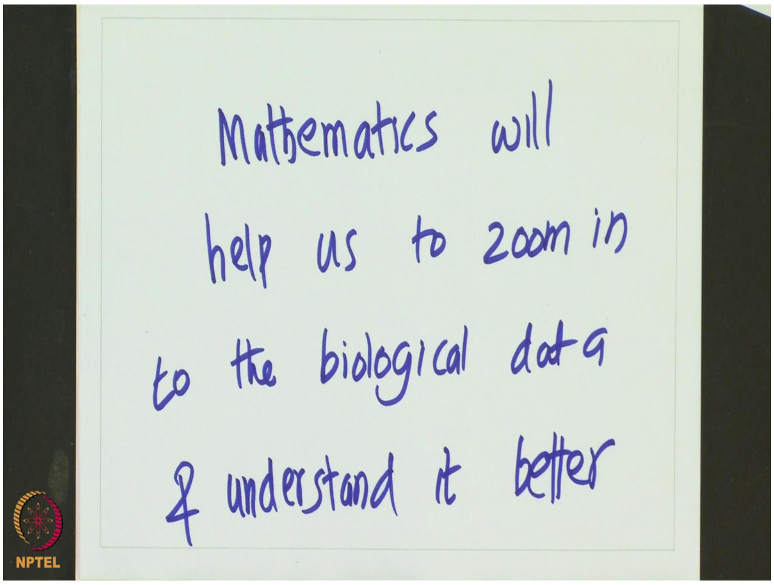
First of all the first part which says Biology is mathematics' next a physics, only better; So, this says about something that we said, in the development of mathematics, physics contributed immensely back to mathematics itself like just like calculus was, lot of calculus was developed to describe the physical phenomena like astronomy and a motion in general. So, and then it became a branch of mathematics. So, that immensely helped. And many branches of mathematics was developed as we want to describe the physical world. So, the physics, mathematics help physics, but physics also contributed back to mathematics. And this cross talk immensely helped both the subjects.

So, just like physics contributed lot to mathematics by inventing calculus and many other areas of mathematics, many other fields of mathematics, many of the branches of mathematics was immensely held by the research in physics or the need of learning of the physical world. The biology, the understanding biological world, if we use mathematics to understand the biological world, it will also help mathematics to develop a some new branches of them mathematics might be developed to understand the biological world. That is the implication of the first part. Maybe we do not know some new branch of mathematics which we which is not really used today might be developed, so that we could understand the living world.

So, this might help the mathematics itself is the first part; Biology is mathematics' next physics, only better; and the second part is very useful for biologists, it says, Mathematics is biology's next microscope, only better! Mathematics is biology's next microscope, only better! We all know that microscope immensely held biology to explore biology as a field. The discovery of invention of microscope revolutionized biology right. So, just like microscope revolutionized biology a Cohen professor Cohen predicts that mathematics would be the next microscope. So, the implication here is that today, we have lot of data available, a lot of experiments can be automated, lot of technological advance has led to a lot of new data coming every day, is lot of genome wide data, lot of data everyday being produced by different labs.

Now, if you want to zoom in and understand what is going on within with all this data, we need some tool to zoom into this data and understand this and professor Cohen suggests probably that mathematics is this tool just like microscope was helping us to zoom into the cellular world cellular, world mathematics will help us zoom in.

(Refer Slide Time: 19:19)

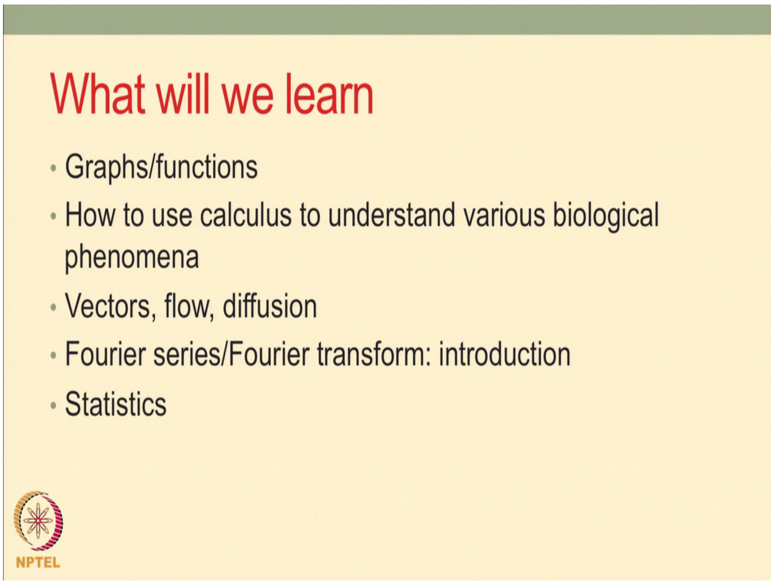


So, this is probably the suggestion here is that Mathematics will help us to zoom in to biological data & understand it better.

So, this is at least the. So, mathematics will help us zoom in that is was the second part. So, not only that, there are 2 parts; 1 says biology would help mathematics that is for mathematicians. But for biologists, it says that mathematics is like the next microscope where that things will that would revolutionize knowledge of mathematics will help us. So, this is a interesting article written by a professor Joel E Cohen, I suggest that you could Google search these precise words and read this article as a very interesting article.

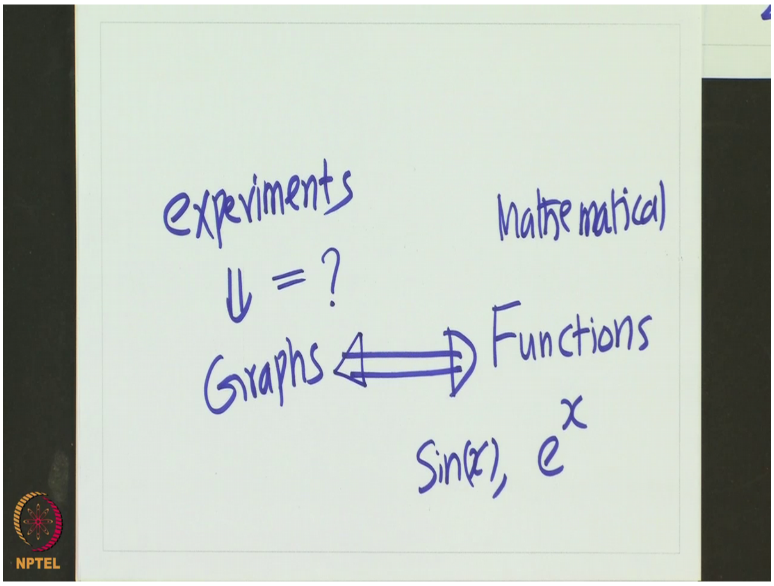
Now, coming back to this course what all we will learn. So, in this course first we would learn Graphs and functions.

(Refer Slide Time: 20:39)



So, when we do an experiment we typically plot graphs. And graphs are related to mathematical functions, formulas. So, first we will learn the connection between graphs and mathematical functions.

(Refer Slide Time: 20:56)



So, this is, we do experiments and experiments would produce some graphs. First of all, how to plot graph, how to think of experiment that would lead to some nice graph. This itself, there are some interesting questions here which we would briefly discuss.

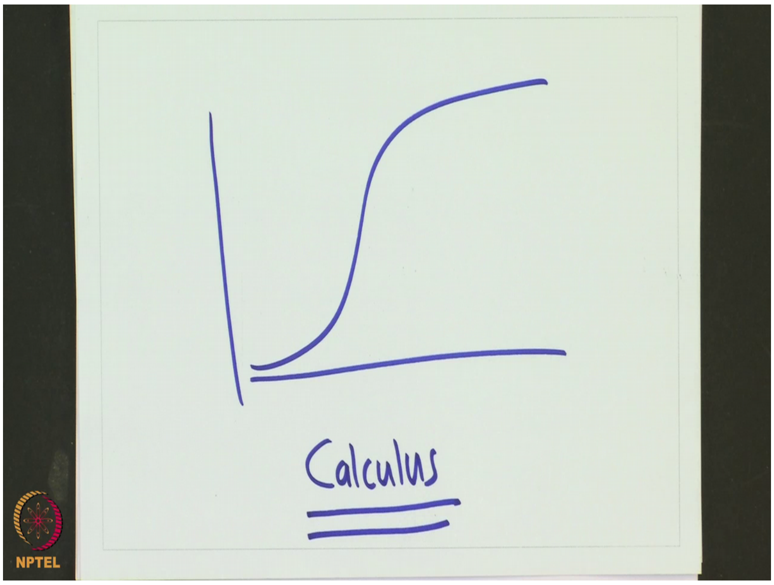
But graphs are related to Mathematical Functions. So, this is Mathematical Functions. So, just like what are functions, just like we would describe just like sin x, e power x, these are Mathematical Functions. And many of this graphs that we would get an experiment are connected to Mathematical Functions and vice versa. So, there is an very important connection between graphs and functions and understanding this is the key in understanding a lot of phenomena.

So, when we say, when we use mathematics to describe phenomena, we would train you to think of the phenomena around us as a Mathematical Function. Every phenomena, everything that we observe as a function as a Mathematical Function, if we could think in that way, it is a trades the training. If we get the training you could think in that way. And if you think started, if you start thinking that way that would open a new world which will help you to learn and gain more insights to the data, to the experiment itself; what experiments you should do, how to design an experiment which would give us a quantitative output. And that quantitative output of course can be represented as the graph and that graph is related to a function.

So, this connection between graph and function, they would help you to design better experiments; an experiment that would give us qualitative output. And how to analyze the data and how to understand and what insights will be gained, this is the cross talk between mathematics which is a quantitative description. And the experiments that you would do and this is something we will try to train you we will. So, this is the first aim is to train you to think in terms of functions, graphs and all that. So, that is the first training that we would like to start giving you in this course. Second is of course how to use Calculus to understand various biological phenomena.

So, many phenomena like growth like which we all know the growth curve, it is all of us, every biology student would learn like various curves and growth curve is a classic example.

(Refer Slide Time: 23:40)



There are many such curves and these are, understanding this curve is very much related to this branch of mathematics called Calculus. And this is an important thing to understand and say understanding this would change a lot of things. Understanding Calculus will change your perspective completely looking at the data. Therefore, it is important to think in terms of calculus mathematics when you think about data.

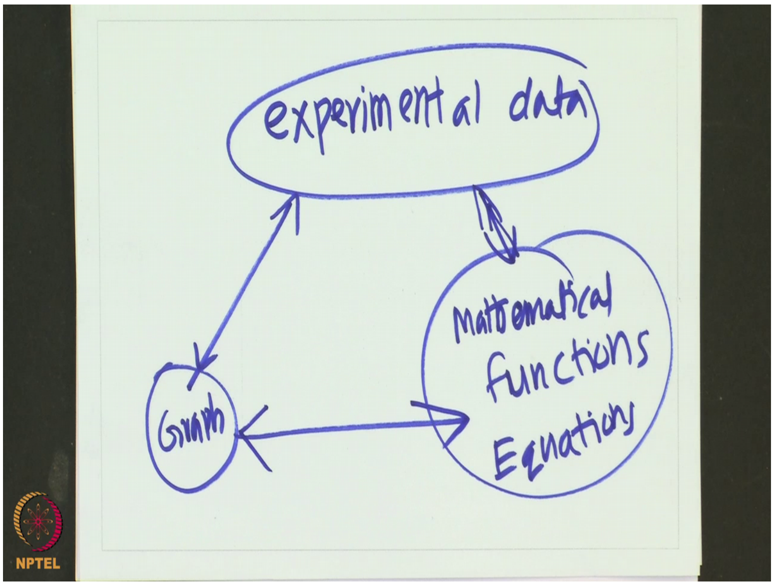
So, this is something you would describe. And how to think of phenomenon in the perspective, within the, after the knowledge of calculus, how to use calculus to understand various biological phenomena. We would then describe like the Vectors like something with directions; for example, flow, diffusion; this kind of things we will describe; which are phenomena that you would see around you and how to use mathematics to describe this phenomena. And then we would use Fourier series/Fourier transform: you would have an introduction to Fourier series and Fourier transforms. Little bit we will familiarize you, because these are a thing that is very often used in structural biology.

So, you would not of course, this is not an advanced course to teach you how exactly to do all this, but it is an Introductory course to introduce you what this, what is it all about and what is it all about and you would get some preliminary understanding of what is Fourier series and Fourier transform and how was it useful. And in the last part, you would have some introductory statistics. Of course, statistics is a, biostatistics is a completely different subject in itself, is a course in itself. But, we will have an introductory statistics part where we would little bit describe how this function this Mathematical Function, of course is useful as a probability distribution etcetera and statistics it will appear and you would connect them and you would teach you some basics of statistics. And we would end with describing you, how we could use this all knowledge to later do some mathematical modeling of the phenomena that we would see.

So, this is the aim of this course. The basic aim is to introduce you to this language of mathematics. So there is an introductory course and familiarize you with equations graphs so that you are, you get enthusiasm to learn more about it rather than an aversion to look at. If you can see any equation after this course, you will be curious to see what that equation is, what is the meaning of that equation is, that is the aim of this course and to think of every equation as a graph which is an also an experimental data.

So, every equation you would be setting to think as a graph and every graph can be connected an experimental data. So, experimental data graph in equations. So, this kind of things that you would.

(Refer Slide Time: 27:05)



So, this kind of relation, experimental data is of course, related to Graph and this is related to Mathematical Functions or equations, Mathematical Function or equations. And this is of course connected to this. So, there is an all connection, I put all arrows. So, these 3 things, we will look at this connection. And this is the aim of this course to familiarize you this. So to summarize, it is an Introductory Course on Mathematical Methods for Biologists. This is for biologists. And this will help you to learn basics of mathematics to understand biological phenomenon and life sciences. With this, I will stop and we will start with the next lecture soon, bye.