Cellular Biophysics
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Introduction
Part: 01

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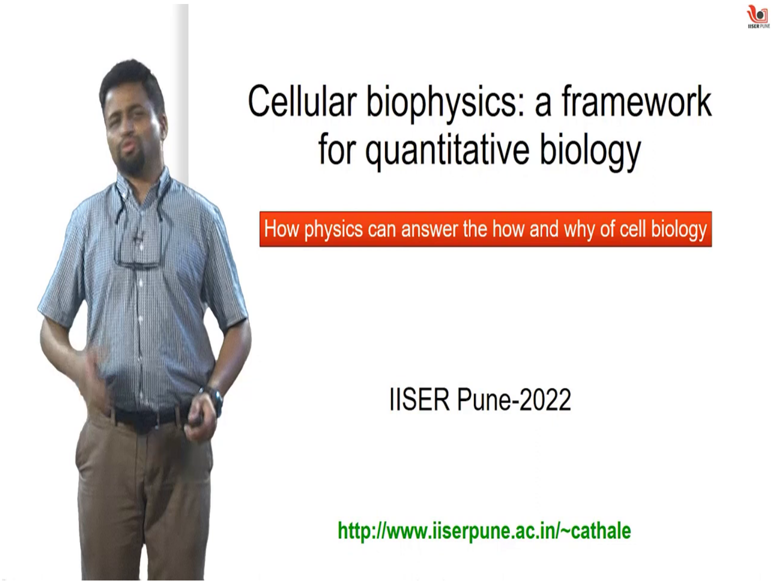

Hi, welcome. I am Chaitanya Athale and this is the Cellular Biophysics course, which we are going to go on a journey with, into an understanding of quantitative biology through exploring concepts in physics, examples in biology, and a blending of the two. Now, in a sense, the large goal of this course, is really to ask and answer the question how physics can answer the how and why of cell biology.

But I hope you will also find that we are not just restricted to cells, because the principles that apply at the cellular scale, I hope you will see apply at higher scales too and at smaller scales too that is to say intracellular as well as multicellular. Now, we will not be touching on Organismal Biology for the limits of constraint of this course. But we will indicate where things apply into more higher scale problems. And for those, of course, you need to take other courses.

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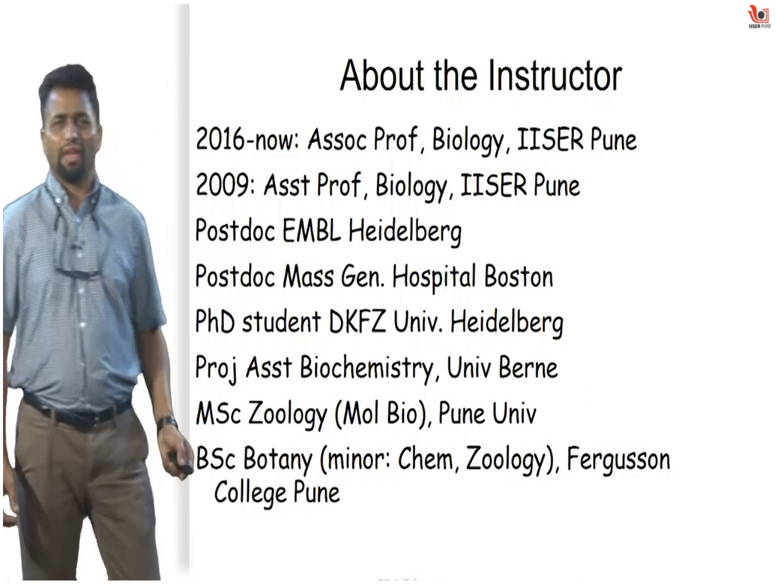

So in this spirit, I just want to introduce myself a little bit, I am Chaitanya Athale, I am an associate professor at IISER, Pune. I have been in this place since 2009. Prior to this, I was a Postdoctoral research fellow in the cell biology and biophysics unit before that I was a Postdoc in Mass General Hospital in the Medical School. And before that, I did my PhD in Germany that was 2003. My background has been a bit diverse, I worked as a teaching assistant at the University Berne in Switzerland for a year or two. Before that, I did a Master's in Zoology.

Now you will really wonder what is Zoologist is doing teaching bio physics, and I hope you will see the answer to that question. I also did a BSc in Botany. Now this is sort of important for me to say it because it is not to say that you should be this. But to also point you to the idea that quantitative biology is for biologists, as well as physicists. And you can be from a biology background and learn some of these tools.

And I hope and you will see during the progression of this course, that these tools and these approaches and these concepts logic, are very powerful, and when used wisely, with some understanding, can give you great benefits in understanding fundamental biology, biological questions, like, Why do animals behave the way they do? Why do birds fly the way they do? Why is evolution driven in the way it is, and the kind of questions that as a biologist you think are most important?

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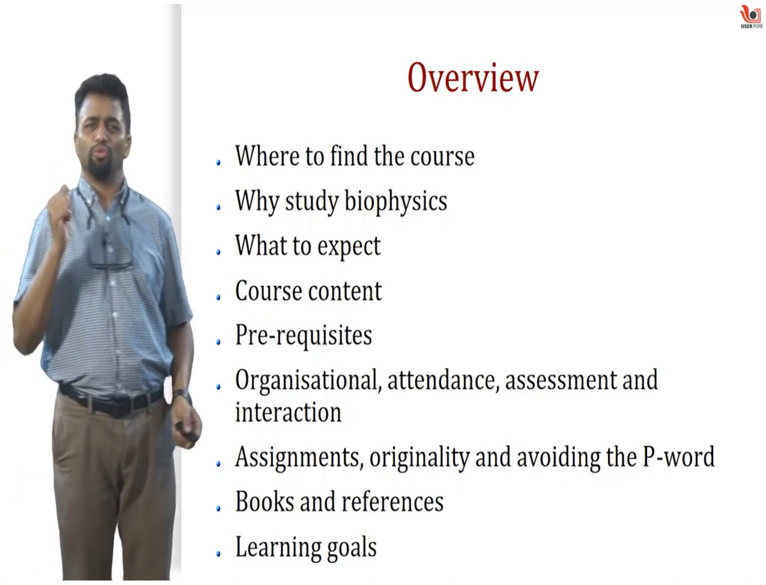

And so broadly, the overview of today's lecture, is that I am going to talk to you a little bit about where you will find the material. And then we will jump to a few questions. And I think it is very important for you to realize that without questions, science is kind of pointless. So we are going to ask the why, why do we study bio physics, what to expect from this course, and what the course contents actually are. I am going to talk a little bit also a little bit about what your background is likely to be.

Now, this is an NPTEL course. This means that many of you may be watching it with very diverse backgrounds, you may be a humanities student, you may be a school student, I do not know that. But I do expect a certain amount of prior knowledge when you come into this course. So, even if you are twelfth standard, or first year BSc, student in Sociology. If you learn some of these prerequisites, then you will make more sense and gain more from this course.

Naturally, the target is typically biology and physics, natural sciences background. Then I will talk a little bit about organizational issues of attendance, assessment and interaction, originality, assessment, and the P-word. And by P-word. I think many of you probably guessed this in the academic context, plagiarism. I will end this session with some pointers to books and references. And what I hope you will learn from this course if you actually finish it. So, let us dive straight into this.

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The broad web based information is available on the NPTEL website, this is where you accessing this course. But I will also post some material on my own Institute website under the rubric of teaching. And if you go to this, navigate to this page here, that is iiserpune dot ac dot in/~cathale. You will land on this page and be able to see some of this information.

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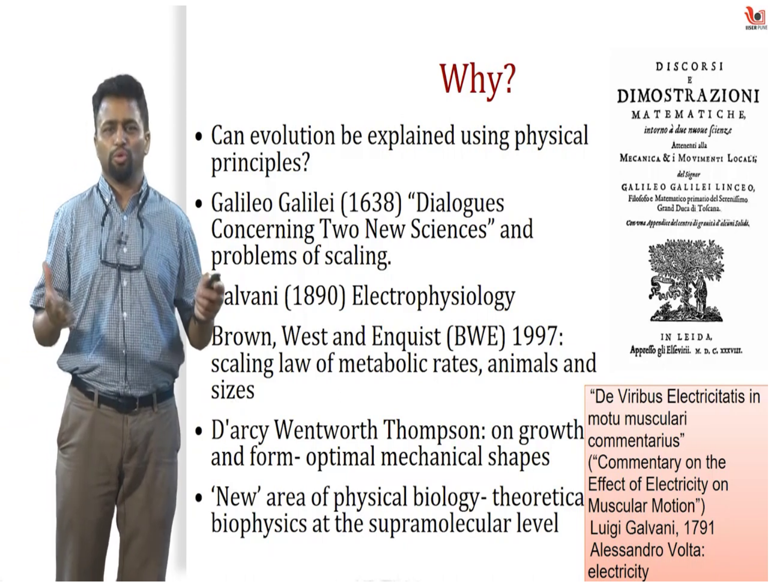

So, it so happens that when we ask a question, why should we study a subject, this can give you a very diverse set of opinions and some of those opinions may not be very useful. So, I will try to be useful. And I will also try to explain to you the motivation is not new. So, for me one of the most important answers to the question why study cellular biophysics? Is that whether we can even use physical principles to explain evolution, we are intrigued about ourselves, we are intrigued as humans.

We are intrigued about the co evolution of symbiotes, like all the gut bacteria, were intrigued about dogs, cats, how they evolved to be with us, cows that domesticate, domesticated by us, but also other animal and plant and microorganismal life which, in a sense, form our entire ecosystem.

So, are there any principles, is it just that in order to understand biology, you need to go into the field and classify every butterfly there is. And my view on this matter is that there are some principles, they are hard to get, they are important to get, but you need investigation, and the hard work that people have done, this is what we are going to talk about in this course.

Therefore, I think studying biophysics is important. And this picture I have put in this corner here is the cover of an original Latin book by Galileo Galilei. Now many of you are probably physics students, and you are very familiar with classical mechanics, celestial mechanics, and the foundation of modern physics and some of the ideas of Galileo. Galileo, incidentally, was a revolutionary guy. He did not look like a revolutionary he did not wear a cap or some funny cap.

He was revolutionary because he asked questions and he asked questions and gave answers those answers at the time when he gave them were against the dogma of the priesthood of that time, and that made some of his answers unfortunately, considered to be heretic he was asked to recant, he was asked to take back what he said.

But the work that he did stands the test of time. And for us, as scientists, this is the most important that you may disagree, people may disagree, but the test of time is the best test of any scientific discovery, concept or law that we may put together. And in this Discorsi Dimostrazioni Matematiche he discussed mathematical and demonstrations, discourses on demonstrations of mathematical laws of nature, which amongst other things, told us something about evolution.

And I will touch a little bit upon it when I talk about mechanics. And you will be surprised how Galileo was so far ahead of his time. I will also try to answer to you questions about things that again 1890 this is not a history lesson, but this is just to tell you that people have been asking these kinds of questions and being curious about them. For a very long time, we are looking at 1638, 1890 with Luigi Galvani, who showed that a frog's leg when connected to a pile, basically copper aluminium, combined with some acid, making a primitive battery would give you stimulus response in the leg of a frog. Now, he called it bio electricity.

Volta came along Alessandro Volta, who then demonstrated that it was probably more due to the electricity generated by the battery not because of biological electricity, but the answer to that question lies somewhere in between in what we today understand as neurophysiology. And so, the point being that people have being curious about this for a while, so studying it, and understanding what they have already discovered and how they discovered it gives us ideas about 'a' the new principles they found, and 'b' how to approach new problems in the light of the kinds of approaches that were very successful.

For me, a very exciting study, which was theoretical, purely theoretical, which tried to unify all of biology through these kinds of physical principles is that of Brown, West and Enquist, sometimes it is shortened as BWE 1997. So, we will come to this century, previous century now. They asked the question, we see so many different animals we see antelopes on the Savanna, we see tigers in the Sunderbans, we see little ants in our backyard and in our kitchen, sometimes, we see microorganisms under the microscope, we see plants of different sizes, we see tiny, one celled plants up to the gigantic trees in the Himalayas.

So, is there anything that connects all of these and surely, since DNA is common protein is common lipids are common. Surely, there should be some common rules also at a higher scale. So, when they asked this question, they found that not so much the size and volume and mass aspects, but the metabolic rates may be a unifying law across all these scales.

Now for those of you who study physics, you are familiar with this idea of scaling behavior. For those of you who study mostly biology, I will talk a little bit about it. Because to me, it is important to both know the detail and zoom out and see the big picture. And this is what we are going to try to aim to do with the principles we discuss in this course.

Now, a book that I find very attractive and every time I try to read it, I never finish is that by D'arcy Wentworth Thompson on growth and form. Now, Wentworth Thompson was a slightly unusual person, he was not a trained engineer. But he had a lot of friends who were engineers at the height of engineering in the United Kingdom in Britain. And he went and tried to ask and borrow the maths that they used to ask whether those can be used to explain how organisms grow from a single celled state.

Remember, you and I, all human beings listening to this? I mean, unless dogs are capable of understanding what you are doing, mostly humans are listening. We were all one cell, right? So, how we go from one cell to this very complex being made up of billions of cells, along with some symbiotic organisms inside us, is a complex question. And in a way to my mind, one of the biggest questions in biology along with evolution, how does this work, this plan of development work?

And so in Darcy Wentworth Thompson's book, he attempted to pull out some of the concepts from 1900s, even 1850s, classical mechanics, and apply them to some of the biological problems, and these are some of the problems we are going to touch upon. So, to answer my earlier question, why do we study, why should we study biophysics of the cellular scale? It is to become familiar with these so that we can now coming to 2022 the year we are in, make more progress and decide whether some of these principles you can discard because you know, just because it is written does not mean it is right.

So, some of the old principles we have to discard we move on we because we find evidence, evidence that contradicts it, and we find new principles in the process. So, in some senses, people argue that biophysics of this kind is a new area. It is a new physical biology theoretical biophysics supramolecular level.

My claim is, and I hope you will see this, that it is new, and it is not new. What do I mean? I mean that the questions are old. But the answers are new, because our technical understanding of methodologies of concepts has advanced from the 1800s and 1700s. And putting these things in the new perspective gives us in my opinion, a lever on understanding the complexity of biology in a way that we could not do before, or never before approach. And that is what makes me very excited about this area. And I hope you will share my excitement as we go along.

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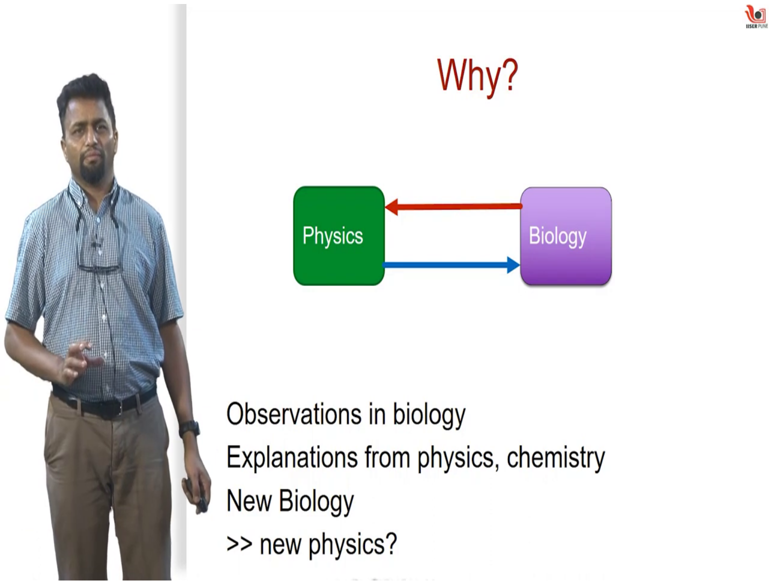

Now, one more question of why is biologist study biology, physicists study physics, why mix the two? And part of the reason is that, of course, for the longest time, and many of you probably have professors, researchers who were trained in the physics field, physical sciences, deals with dead material, Bhautic shastra, as sometimes it is called in Hindi, Marathi.

But Jaivic shastra, or live material was studied under biology, BIO logos is the Greek root of this. So, what is the point? So, initially, most people think, okay, physicists will invent an instrument, they will make a microscope, they will make a telescope, they will make a spectroscope. And then biologists will apply that and learn something from it. So, the information goes from here to there.

But what about the reverse? What about the fact that biological systems are sometimes so strange that things can go from here this way? And this is part of the question that I hope we can address in this course, at the end of it, when we summarize whether the explanations from biology have led to any new physics at all.

My claim to you is yes, but bear with me and be like a good scientist and wait for the evidence and decide for yourself.

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So, I am going to take a pause here while you admire this beautiful picture of a lizard. When we go to the what question of this course.