Cellular Biophysics
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Part: 03
Introduction

Hi. So, welcome back. So, what are we going to talk about in this course? And what are we going to discuss what kind of topics we are going to cover?

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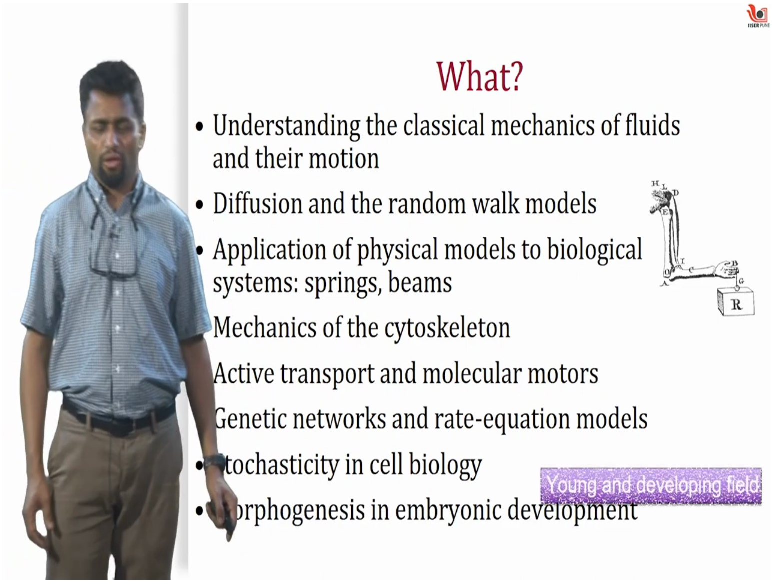

So, we are going to understand the classical mechanics of fluids and their motion, because all of life is made up of fluid. We are going to discuss a few standard laws going back again to Newton's laws of fluids, and apply them to biological systems. And then we are going to talk about diffusion. Now many of you have heard in the molecular biology context, about something called recruitment of how a signaling system can produce a signal from one place and it gets transmitted through the cell.

Diffusion is the driving force, we will discuss a little bit of the details, some of the maths, some of the physics of it. And we will also discuss something called the random walk model. Because that is a key to understanding a lot of these statistical processes, we will then of course, go from that to applying these physical models to biological systems in terms of springs and beams.

This is the same thing that will be something similar to your spring balance system, and beams just like the beams that hold our buildings together. And it is surprising because these apply to the mechanics of the cell. Now, none of the cells are like your concrete buildings, because they do not have just rigid rods. But there is something interesting to be learned by using these physical models to the cellular context, in terms of the cytoskeleton.

We will then go on to something that is really fascinating for me personally, which is the process of active transport, at the expense of chemical energy, like ATP, which drives motion inside a cell. And this also drives our nerve transmission. This drives our cell division; this pretty much exists everywhere we look inside a cell. Ironically, bacteria get away without it. And we will talk a little bit about why?

We will proceed to the most fascinating part of biology, which is genetics, and we will discuss specifically genetic networks and rate equation models. The maths involved involves a little bit of ordinary differential equations, and I hope, we will keep all of you up to the same speed so that you can follow this part. And then I will proceed to discussing some models of stochasticity in biology and morphogenesis in embryonic development.

What is important to note here is that this is a young and developing field, you will learn new things, these things in terms of what question will be useful to you, and they will also provide you hopefully insight into what is then broadly considered quantitative biology.

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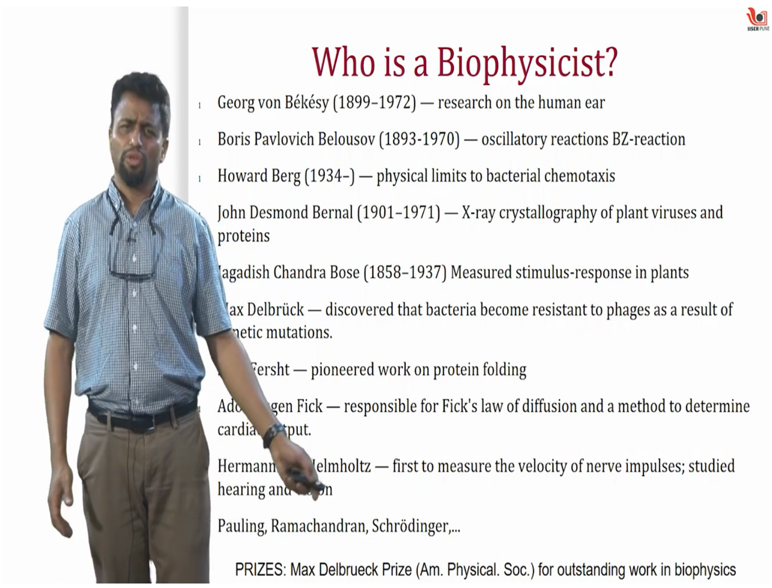

So, maybe we should ask ourselves, if you finish this such a course and you say I am a biophysicist, then who are the predecessors, who are the illustrious examples of biophysicist. So, you can look at this Georg von Bekesy, who did research on the human ear on hearing. Boris Pavlovich Belousov, some of you have heard about Belousov–Zhabotinsky reaction, Howard Berg, who just passed away actually in 2022.

So, I should probably update this, who discussed the physical limits to bacterial chemotaxis. JC Bose who measured stimulus response in plants because this was initially thought to be plants are sort of non-sentient, they do not react. Max Delbruck discovered that bacteria become resistant to phages as a result of genetic mutations, in fact, set up some of the classic experiments that demonstrated the genetic basis of life.

Alan Fersht who pioneered work on protein folding, Eugene Adolf Fick, who is responsible for Fick's law of diffusion and cardiac output. Hermann von Helmholtz, who first measured nerve conduction velocity and studied hearing and vision. Pauling, Ramachandran, Schrodinger, the list can go on. So, there is a prize for this biophysicist area. It is called the Max Delbrueck prize from the American society for outstanding work in biophysics. So, this is a formal discipline unto itself.

So, I just want to emphasize to you that being a biophysicist is not a bad thing. I know that in many contexts in your colleges, you may see that physics department is one building, chemistry department is one building, biology department is one building, but there are disciplinary boundaries that can be crossed into give rise to productive and fruitful science. And I hope you will enjoy learning from me on this.

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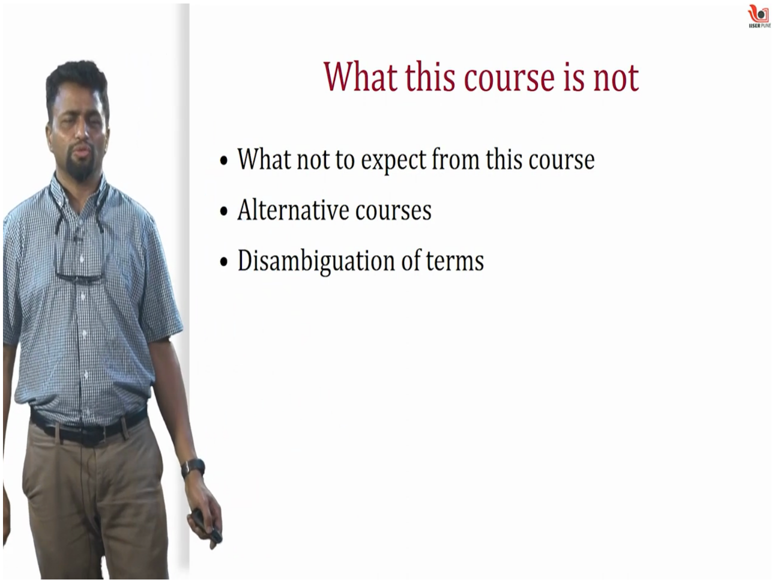

So, what this course is not however, and what you not do not want to expect from this course and alternative courses, and we will talk about right now.

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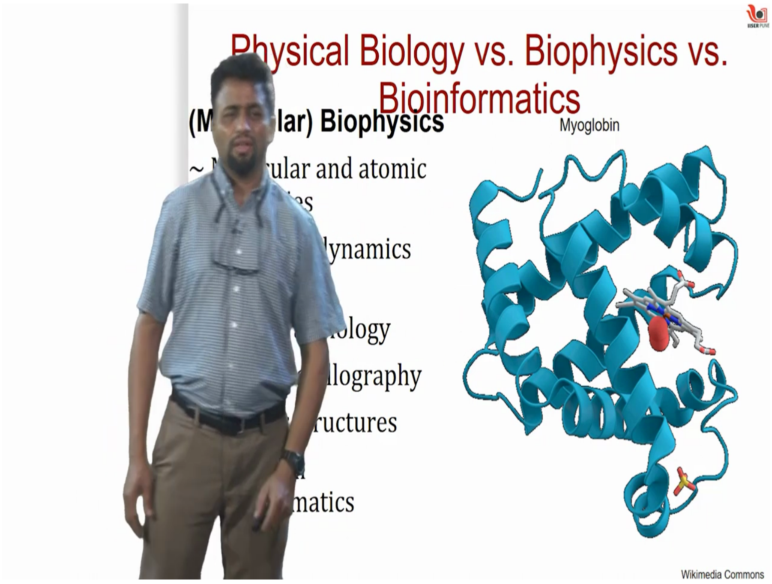

So, what is the difference between physical biology and biophysics and bioinformatics? So, in a way molecular biophysics is what many of you are familiar with maybe in your colleges, you have heard about this sort of atomistic approach to biology through molecular dynamics, structural biology, X-ray crystallography, and NMR and structural based bioinfomatics. And many of you have probably been excited about docking and creating sort of 3d pictures of ligand receptor binding and so on and so forth, because these are very important for drug discovery.

Now, we are not going to talk about that. Now this is not because I do not think they are interesting. But it is because more, they are a bit aside from the point that we want to cover over here. So, this kind of a picture, I will probably not be showing you, which is a beautiful ribbon diagram of a protein. For those of you can read this very quickly here, it is myoglobin, muscle cells.

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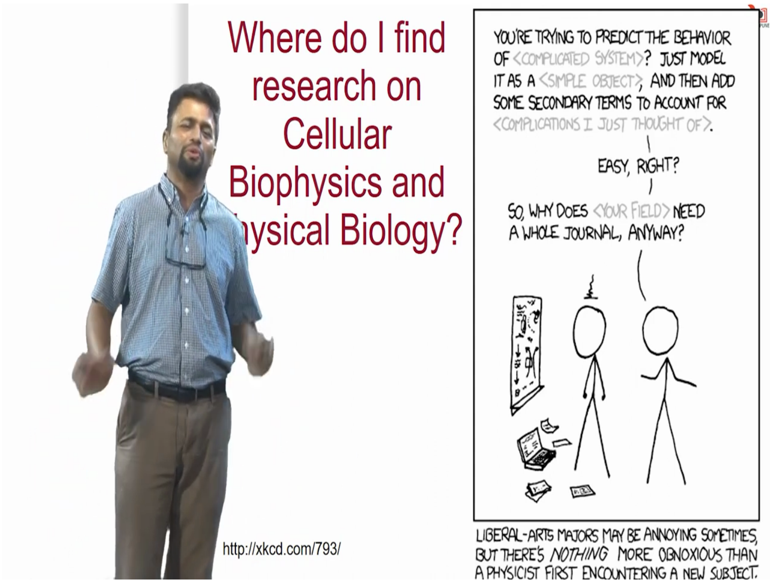

So, where do I find research on cellular biophysics and physical biology? These are questions that many people will ask because you know, it is always nice to know that there is a field and every discipline has its own has its own specialists. But is there anything where you can start reading and this joke cartoon over here basically tells you that oh, someone says you are trying to predict the behavior of some complicated system, just model it as a simple object.

Secondary terms will be added to account for its complications. And then you do not really need your own journal, you do not need your own discipline. Biophysics is just physics, according to the physicists and biophysics is just biology, according to the biologist, so we do not need this subject at all.

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Now, I am going to try to point you out that reality is otherwise there is a whole bunch of journals in this field, and you are welcome to look up these after you finished watching this lecture Soft matter, Biophysical Journal, Physical biology, because even an Indian Journal of Biochemistry and Biophysics I have not seen too many articles in it recently. But indeed, these have been around for a while European journal biophysics journal, PLOS computational biology, molecular systems biology, Bioengineering.

Now, you will notice that the top line actually says the word biophysics in their names, although soft matter does not. But the lower one has PLOS computational biology. Why do I include this? Now, it turns out that one of the strong and very successful approaches methodological approaches in biophysics has been computational. So, you will actually find a heck of a lot of work in that.

Now, systems biology, now systems biology to some people, it is just genomics and proteomics, but systems biology in its original conception was essentially nothing but an extension of biophysics. And, in some senses, the idea that you can look at something as a whole and design, mathematical and physical models that can explain the behavior of the parts. And this is why you will find quite a few papers in that and of course, there are interfaces and overlaps. So, even bio engineering, in some senses has enormous relevance to biophysics and will probably pick a few papers from those journals.

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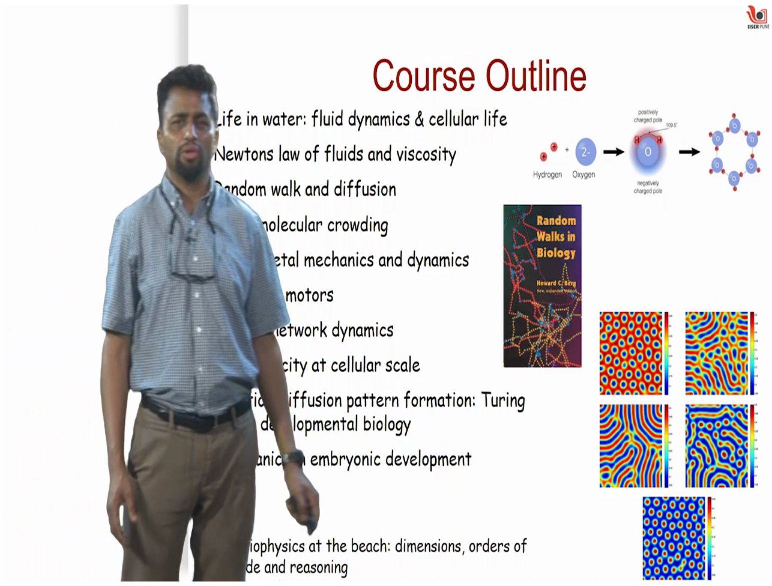

The course outline as such, is specific in terms of the topics we will cover, and we already have discussed this in the course outline, but we will start with life in water fluid dynamics and cellular life, Newton's law of fluids and viscosity, Random walk and diffusion, Cytoskeletal mechanics, Molecular motors, Genetic networks and dynamics, Stochasticity at a cellular scale, Reaction diffusion patterns and turing how Alan turing's work meets developmental biology and mechanics in embryonic development.

A bonus topic, which we will pop in once in a while is on the dimensions or magnitude and reasoning. I like to call it bio physics at the beach, we would not actually go to a beach, sorry, but you will see that there are some things you can do without any experimental tools just using common sense logic, some simple principles of biology and physics, and some reasoning, logical reasoning.

These pictures here are indicative of some one of the books that I am going to follow quite a bit random walks in biology, I urge you to at least try to get an ecopy of it and if there are further questions, we can find a way to specifically point you to resources.

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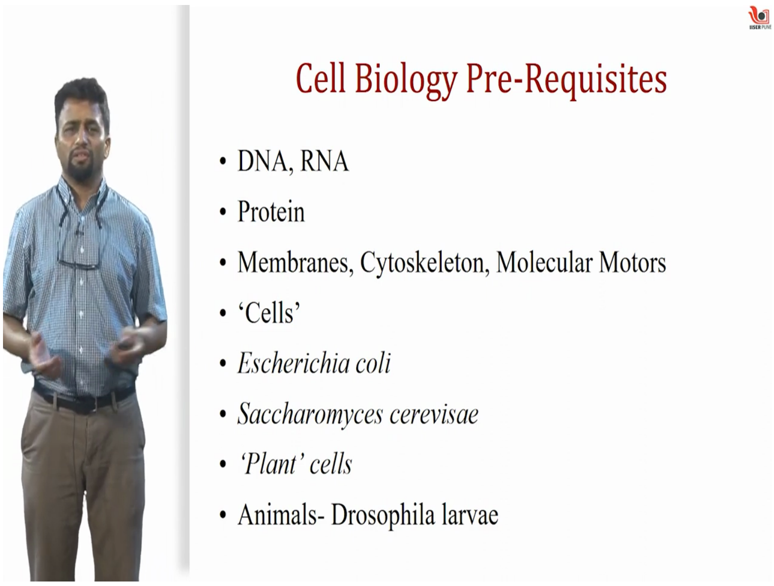

The cell biology pre-requisites are that you need to know what it is DNA and RNA are proteins, membrane, cytoskeletal motors, molecular motors, where will you find this? Well, biochemistry textbooks from Lehninger from Albert's the cell biology textbook of Albert's these are the classic references for these. This is partly why I know assume that you have already studied some of these before.

For cells, we will talk about Escherichia coli, Saccharomyces cerevisae, and generic plant cells. And for animals, we will talk mostly about Drosophila larvae, we will not touch upon other non-model organisms because of the complexity of the behavior for those who actually need to take specialized courses.

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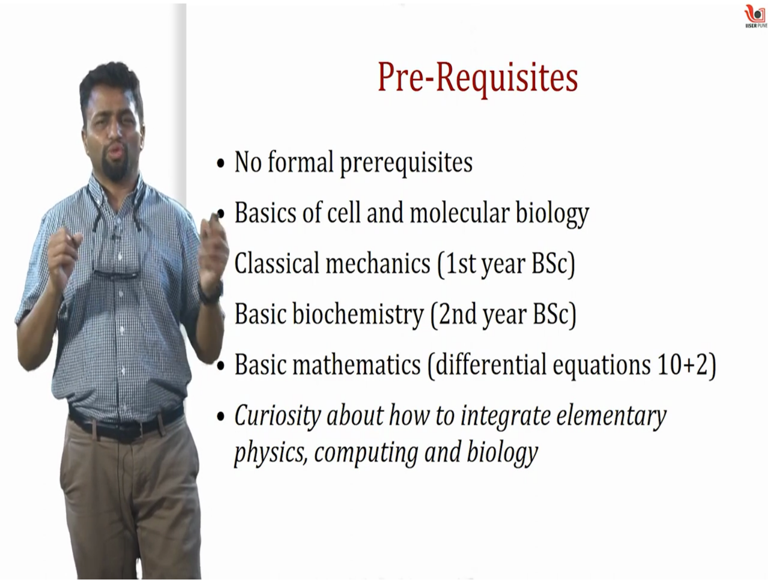

So, the pre-requisites in my way are that there are no formal prerequisites other than the fact that you need to basic cell and molecular biology, classical mechanics of first year level basic biochemistry of second year BSc level. Basic mathematics differential equations up to 12 standard are sufficient, but you need to have had maths at least in your 12 for this to make sense.

And you really need to have a curiosity about how we can integrate these elementary principles of physics, computing and biology. If you do not have that curiosity, you will probably find this course a bit of tough going, but I mean, I am almost positive that if you come with a curious mind and these basic prerequisites, you will do well.

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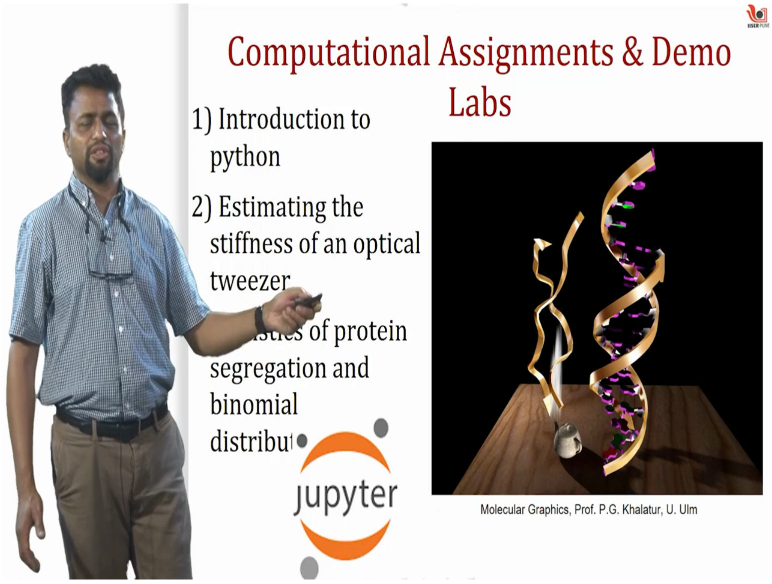

So, the computational assignments and demonstration labs are going to be about mostly introduction to python, estimating stiffness of an optical tweezer, statistics segregation binomial distribution.

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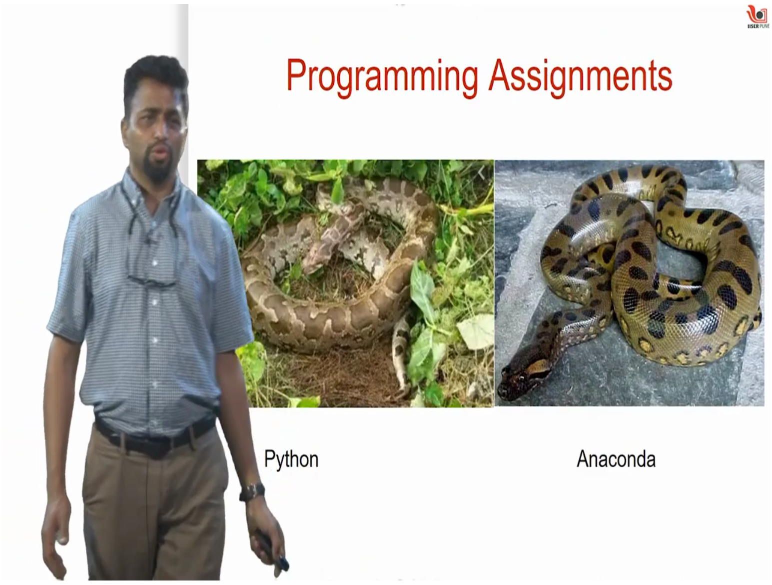

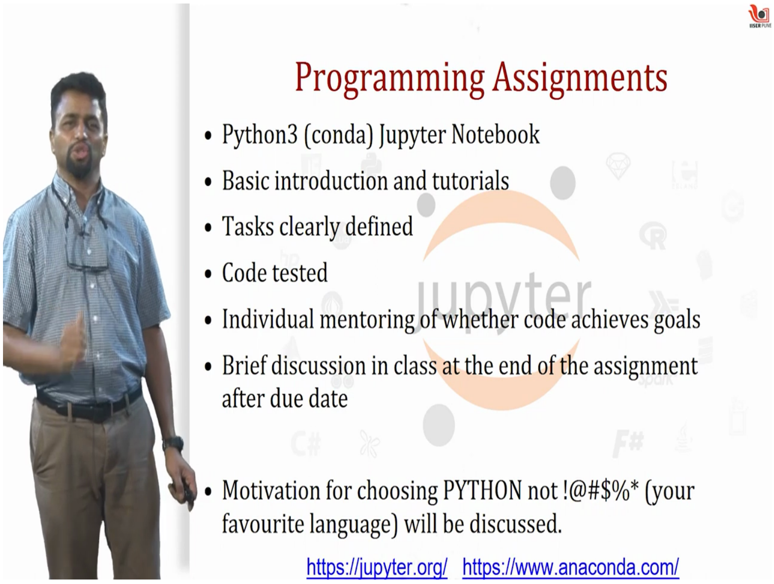

The tool we are going to use is Python. So, not this Python, but the programming language Python. And we will be using it in the environment of Anaconda again, another fat snake. But none of these are dangerous. So, you will find that jupyter.org and anaconda.com give you all the tools that you need to install this we will have a very elaborate discussion on this do not worry, this is just to remind you that we are going to be using conda Jupyter Notebook.

Now there are some tricks and tools by which you can do this online. And we will discuss the details of it. After we go through the basic introduction and tutorials with clearly defined tasks, code testing and individual mentoring. Brief discussion at the end of the class will happen after the due date. The motivation for choosing Python is that you know, many people have favorite programming languages and some of you may not even have looked at programming before and do not be afraid.

Programming is a logic it is the logic is the important thing. If you do not have logic, then of course, there is a problem. But if you are willing to exercise your logical skills, then you will succeed.

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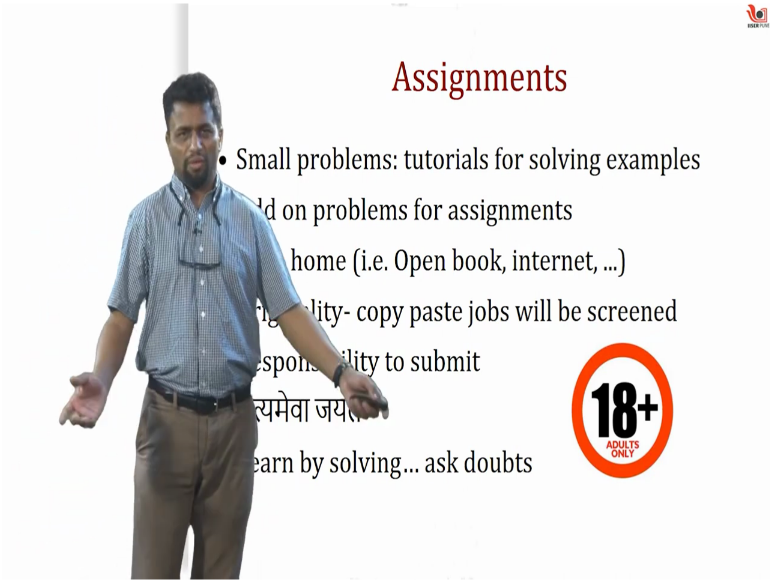

The assignments will be based on problems and tutorials and take home assignments these are now online. So, we will have a system through the NPTEL framework for evaluating you, as well as the timeline you are almost all assumed to be 18 plus, so I expect you to be responsible and honest and truth always prevails Satyamev Jayate.

This is the log motto of our country and I hope you follow the motto of this country at least to its actual meaning not to the fact that I have to try to find and police you. You must try to learn by solving because if you do not solve it yourself, if you ask someone else to do it for you, you will never learn you will complete the assignment I agree, but this will not be useful for you. So, please try to do things on your own.

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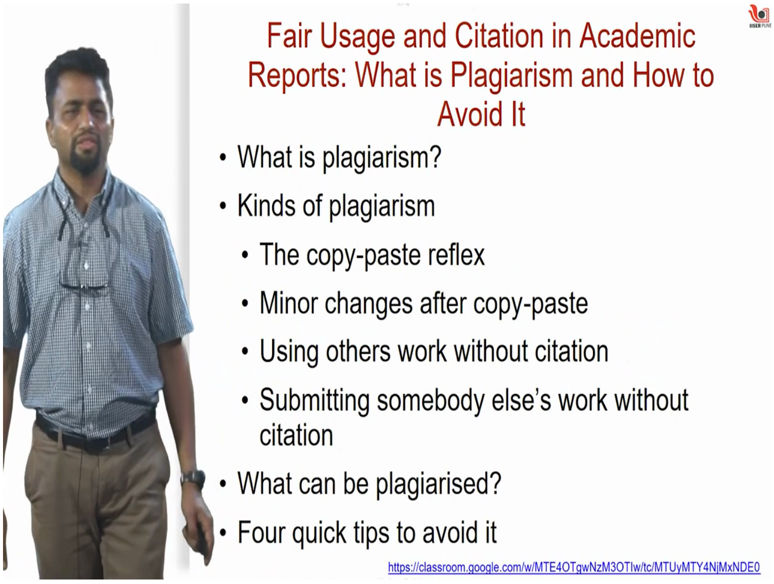

Now, an important point I want to bring up is that there is something about fair usage and citation and academic reports anything that you write to us, especially if you are using it as a short essay type answer, then you need to site the source where you have got the material from. Now, I will share with you a document which is what exactly is the definition of academic plagiarism, the kinds of plagiarism that you can find in the literature, which you should be avoiding.

You must try to tell yourself that copy pasting something from somewhere and submitting it in a situation when you are required to put something original is not okay. Not acceptable copy paste is not ok. Because the problem is when you use other people's work without making it very clear that it is actually other people's work. You are already plagiarizing. In fact, if you then submit someone else's assignment, it is clear and clear plagiarism.

Now, I have had a lot of debates with students in the past, I think some of them have been educational, some of them have been disturbing. I think we will have a discussion on this. I am glad to talk about it if you have any doubts, but I will also be providing you some quick tips on how to avoid it. This link will be put up in the NPTEL workshop environment.

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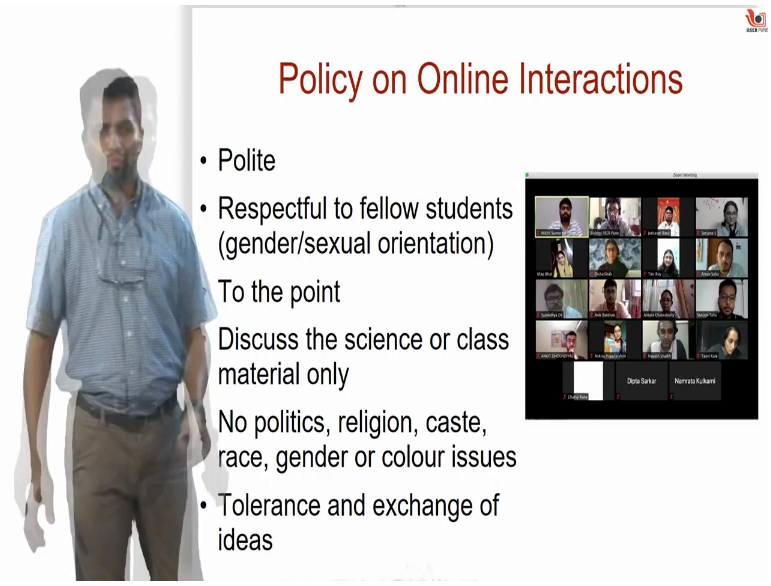

There are policies on online interactions, I would expect you all when you are in live classes or in your tutorial sessions to be polite to be respectful depends independent of your gender, sexual orientation, your sex male, female, non-binary, you must be to the point and your questions are try to discuss science and class material only. No politics, religion, caste, gender color issues, this is not okay. This is not acceptable behavior, no trolling people, no harassing people. This is what we call a good academic environment, a healthy academic environment.

I expect you, all of you who are coming here to learn to actually be focused on the learning. We always make friends, by the way, and I hope that those friends are based on science and not on other things.

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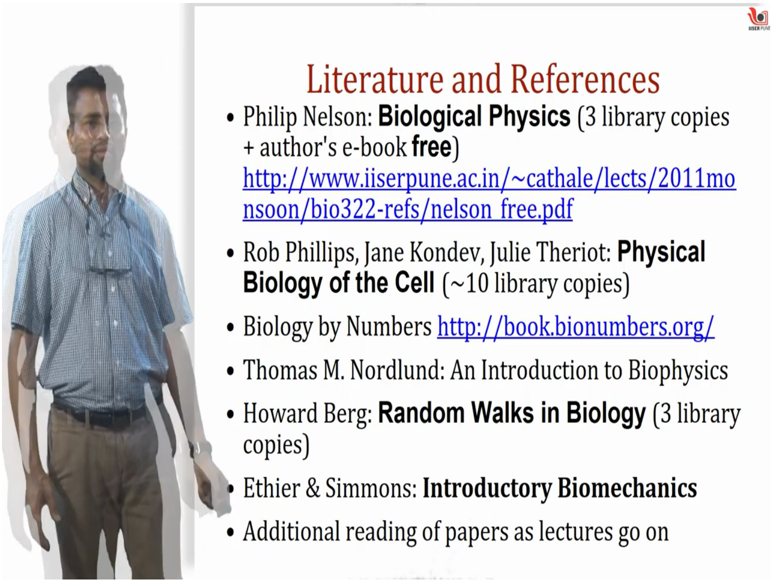

There are a whole bunch of references that I have put together and these will also be provided to you in a PDF form. The book by Philip Nelson on biological physics, Rob Phillips, his book, biology by numbers. Introduction to biophysics by Nordlund. Howard Berg's random walks in biology, which I mentioned earlier, Ethier Simmons, introductory biomechanics and additional reading are all part of this material.

Now, of course, that does not mean that you have to sit and read them. It only means that if you would read more than what I am talking about, those are the places to go. Remember classroom is only a start point not the endpoint of your learning process.

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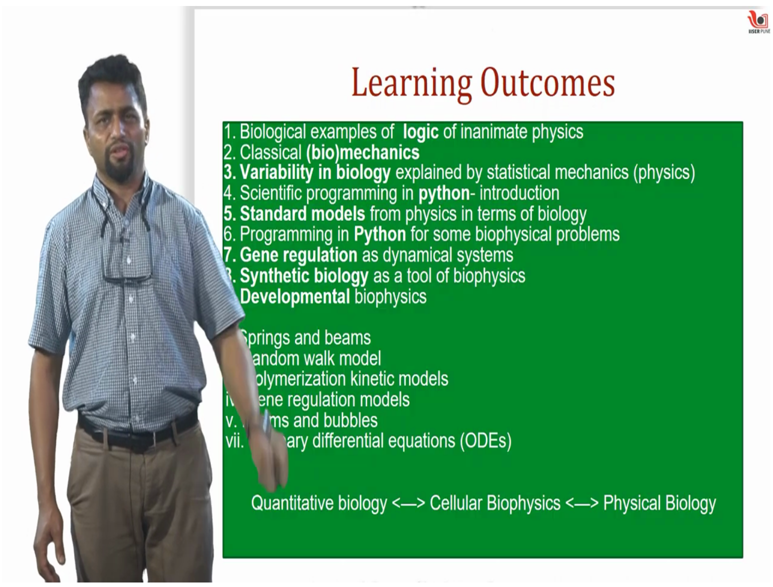

The learning outcomes that I think you are going to get, what are you going to gain from this course is that you will look at biological examples of inanimate physics. Because in the same sense, that if you remember in your high school physics you talked about, we talked about bouncing balls and projectile motion. We are going to talk about only biological examples, and try to put the biology in the context of physics.

You are going to learn at the end of this course about classical biomechanics. You are also going to learn about some statistical models that allow us to make sense of the variability in biology. Because without the physics, much of these things will just become a little pointless. You can do biostatistics. But it is not the aim of the course. The aim of this course is not to do statistical testing, but to understand the why and the how of it.

You will also learn some standard models from physics in the biological context, and programming in Python, and gene regulation as dynamical systems, you will realize that synthetic biology, which is often considered to be like the new revolution after biotechnology, and recombinant DNA technology, is a very powerful tool for understanding as well as exploring biophysics.

We will end with developmental biophysics, which is a new and upcoming field. And I hope that those of you who study this will maybe continue to pursue some of these subjects in your future endeavors in education or even in research. The models, the standard models that we are going to talk about our springs and beams, random walk model, polymerization kinetic models, gene regulation models, foams and bubbles and ODEs models.

In a way, what you will see hopefully, is that we go from cellular biophysics in the direction more of more biology in terms of quantitative biology in an interval more physics in terms of physical biology. And this interplay, will learn help you learn to appreciate how these crossing of interdisciplinary boundaries gives you a deeper insight into the biology, which is what the aim of this course is to give you a tool of the mind to approach biology from a quantitative perspective.

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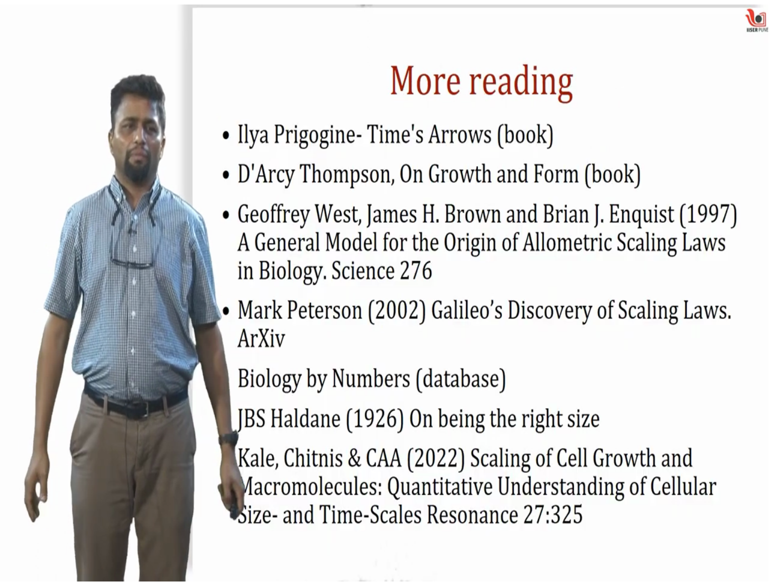

There is much more reading. There are things I will not have time to cover. For those of you want to do this extra reading. You are welcome to do it. Ilya Prigogine Time's arrow is a classic, Prigogine incidentally is a Nobel Laureate. Darcy Wentworth Thompson's book which I mentioned on growth and form.

Brown and Brian Enquist speak classic paper in Science. Mark Peterson's Galileo's discovery of scaling laws, biology by numbers, which is an online database, JBS Haldane on being the right size, and no recent paper that we published in resonance, which is Science Education journal.

So, feel free to read. I hope you enjoy this journey. And I hope I look forward to intense and interactive coursework with you and take you to a point where you appreciate the power of these tools and the learning lessons in terms of understanding quantitative biology. Thank you very much for listening.

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And next time when we meet, we are going to continue on fluids, life in fluids, life off fluids, and fluid mechanics. So, thank you very much, and see you next time. Bye bye.