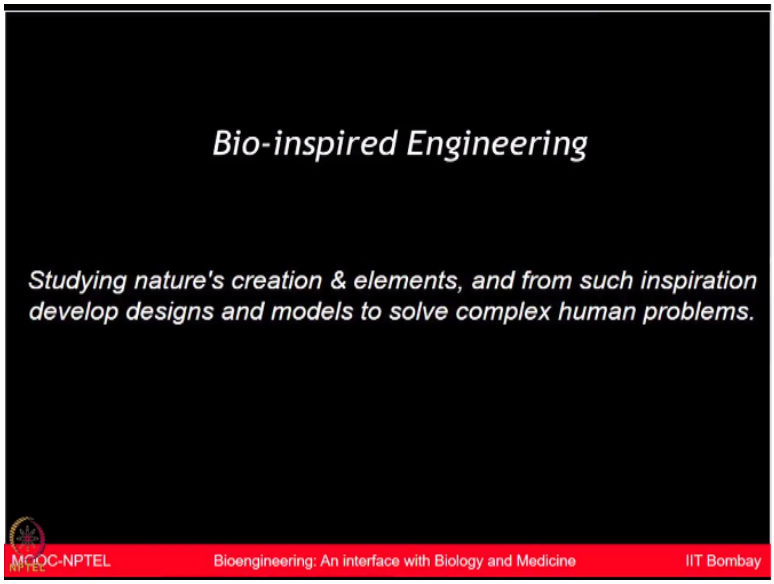
Bioengineering: An Interface with Biology and Medicine

Prof. Sanjeeva Srivastava
Department of Biosciences and Bioengineering
Indian Institute of Technology – Bombay

Lecture - 02
Why Biology for Engineers: Part-II

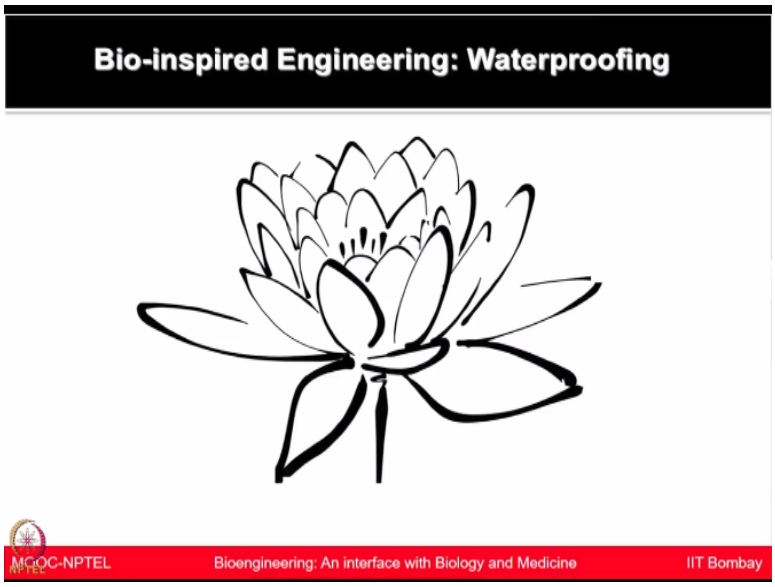
Welcome to the MOOC NPTEL course on bioengineering an interface with biology and medicine. In previous lecture, we had discussed various basic problems which affect all of us equally irrespective of which discipline biology, medicine or engineering we belong to. Today, I will try to provide some examples on how bioengineering has already initiated advancements in multiple disciplines of healthcare and technology. Let us first start with bio-inspired engineering.

(Refer Slide Time: 00:51)



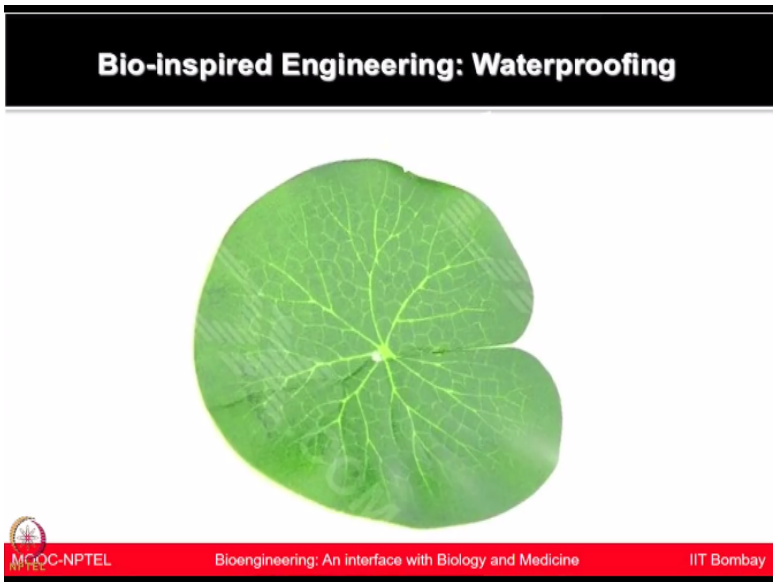
For studying nature's creation and elements and from such inspiration developing design and models to solve complex human problem comes under bio-inspired engineering.

(Refer Slide Time: 01:04)



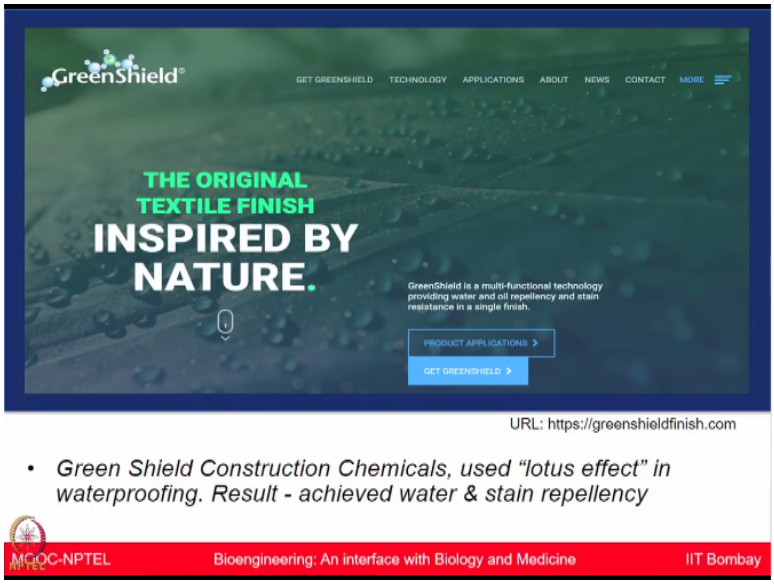
Let us take couple of examples here for bio-inspired engineering. Look at this flower which is lotus flower and its leaf.

(Refer Slide Time: 01:13)



They provide us an example for waterproofing. If you look at the leaf from the lotus, it has the crevices of microscopic roughly surface to strap the air upon which the water droplets float. So lotus gives us lesson for waterproofing.

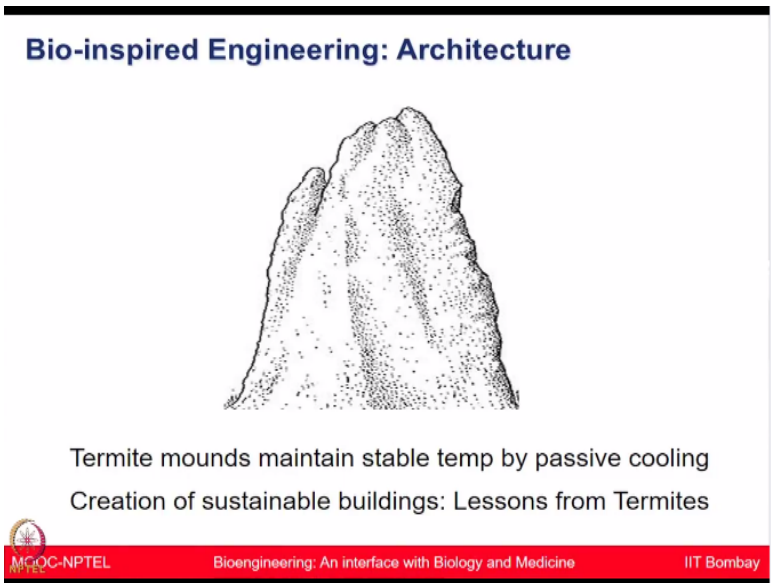
(Refer Slide Time: 01:35)



Now this observation was utilized by a company Green Shield which is a company inspired by the nature. They have made the chemicals which use lotus effect which can be used for the waterproofing in the paints. Just imagine that you know in Mumbai and many parts in the world so much rain happens and buildings look so ugly because the paints will wash off as you know with the heavy rains.

With having these kind of waterproof, paints could be so useful for these building and one could achieve high water and stain repellency.

(Refer Slide Time: 02:11)

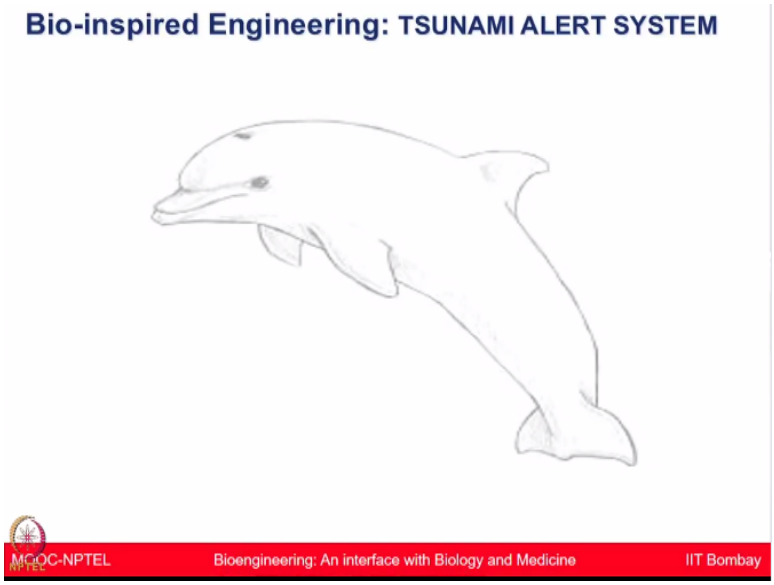


Let us look at another example for architecture. These termite mounds they maintain very stable temperature inside by the process of passive cooling. The creation of sustainable buildings one could take lessons from these termites.

(Refer Slide Time: 02:30)

Look at this elegant building in Zimbabwe Eastgate Building. Their air conditioning system is modeled on the self-cooling mounds termites and has resulted into mechanical or passive cooling system which has used 10% energy for ventilation, then what is used for the conventional building. Just imagine that this minor observation of architecture from termites have resulted into such an efficient and elegant building which uses very less power and it still provides the cooling system for the people who live inside.

(Refer Slide Time: 03:11)

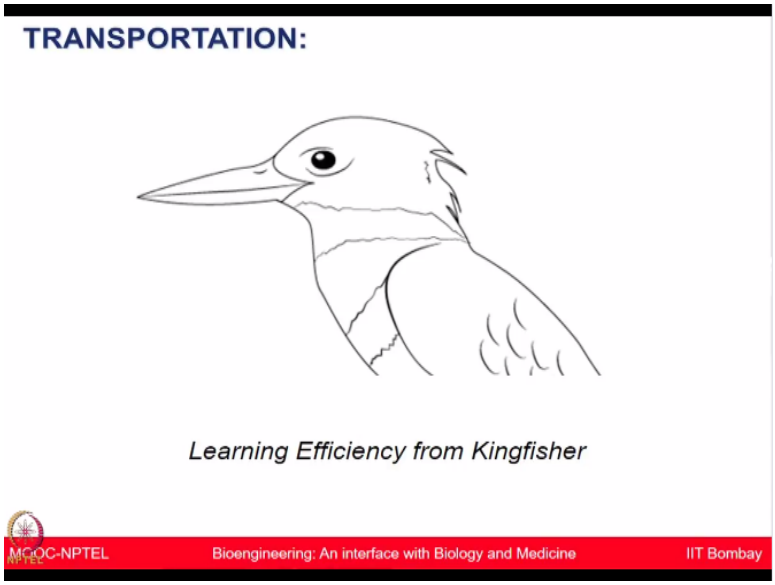


Now let us go to another example. On the screen, you can see the dolphin. Dolphin provides inspiration for Tsunami alert system which can be used for warning people about Tsunamis. Dolphins in their family they recognize calls almost 25 kilometer away when they are in the water to cope with the sound scattering behavior of the high-frequency.

(Refer Slide Time: 03:38)

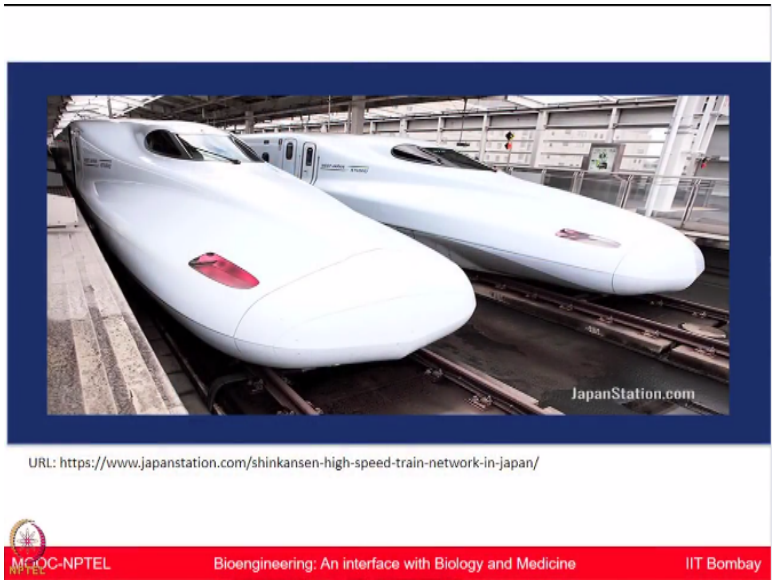
Now a company EvoLogics, they use this particular understanding from dolphins and developed high-performance underwater sonar and underwater robotic systems which has resulted into high-performance underwater modem for data transmission which is currently employed in Tsunami early warning systems in Indian Oceans.

(Refer Slide Time: 04:03)



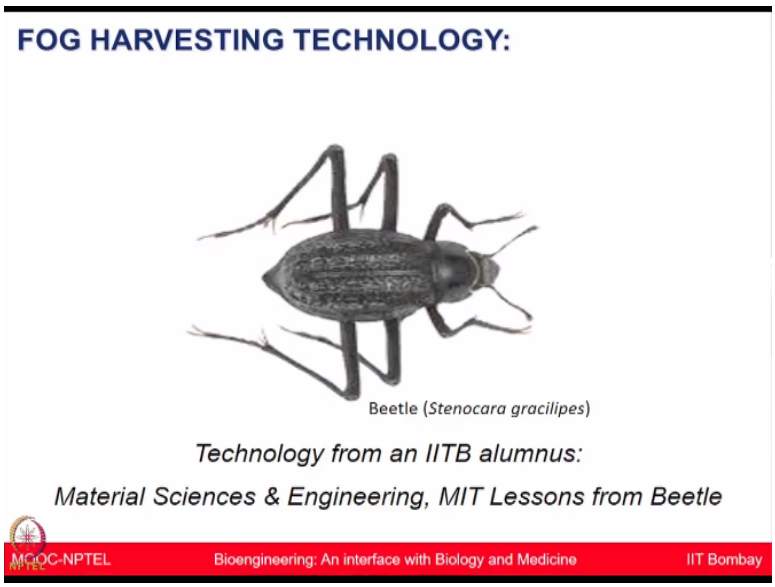
Let us now move on to another application transportation and look at this bird on the screen which is Kingfisher. People have taken the learning efficiency from Kingfisher and a chief engineer and birdwatcher in Japan Eiji Nakatsu.

(Refer Slide Time: 04:23)



He modeled the front end of Shinkansen bullet train which is inspired from the beak of Kingfisher which has resulted into very quiet train and less electricity and it travels much faster. So people who are living nearby they used to face lot of problems because of the noise from these trains and because of the way Kingfisher goes in the water splashes the fish the silence that kind of observation help this birdwatcher to model the front end of this particular train which is the superfast bullet train in the world.

(Refer Slide Time: 04:59)

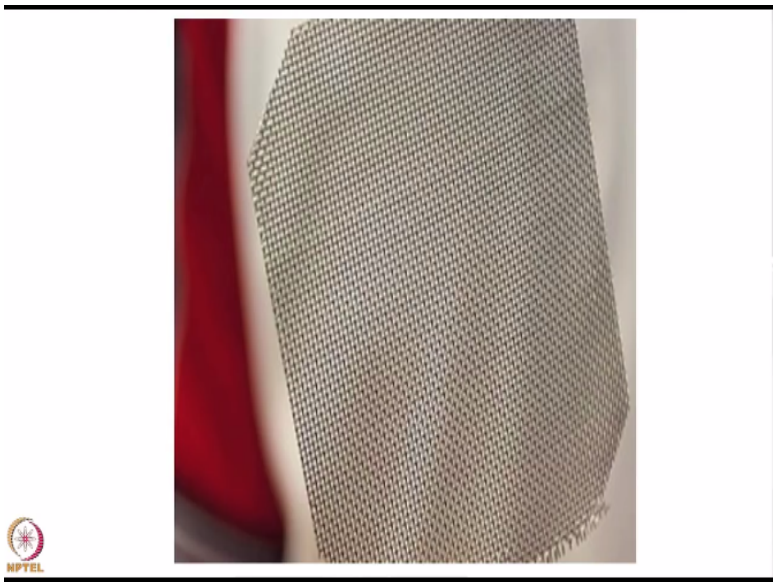


Let us now talk about fog harvesting technology and lessons have been taken from the beetle which is a Stenocara gracilipes. The technology from an IIT Bombay alumnus who studied at MIT, he took lessons from this beetle.

(Refer Slide Time: 05:16)

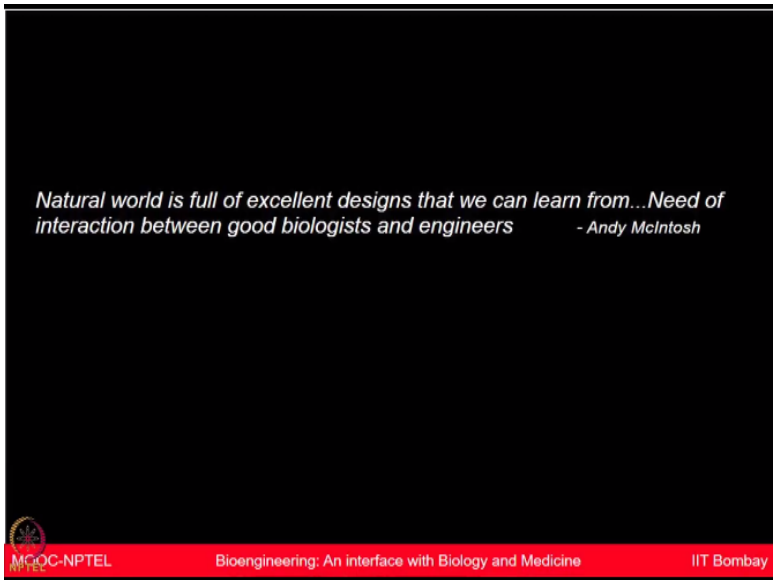
And then developed this meshes which kind of mimics the similar work what these beetles do, so (()) (05:25) beetle they collects water droplets during the morning fog hours and then trying to roll back and let moisture roll down into its mouth and therefore it can conserve the water and it still fulfill its water requirement in the desert area.

(Refer Slide Time: 05:41)



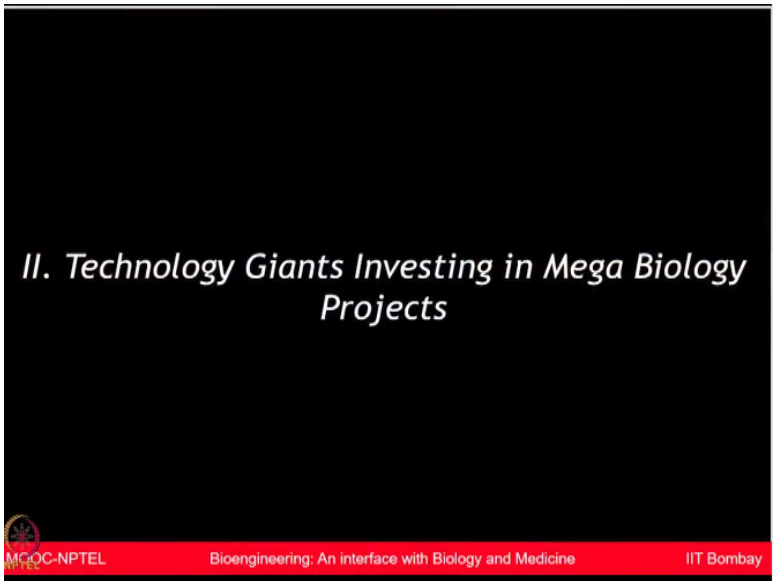
So they developed a device which consists of fence like meshes to attract droplet and then that could be dripped into the container and now the villagers who are living in the surrounding area who were so much affected because of desert and they did not have drinking water they are at least able to collect some drinking water in the morning hours.

(Refer Slide Time: 06:03)



So as Andy McIntosh has mentioned the natural world is full of excellent designs that we can learn from. There is a need of interaction between good biologist and engineer to transform many of these observations into devices and very useful outputs. Let us now discuss some of the examples of different projects which are being pursued by technology giants who are really investing heavily right now in the mega biology projects.

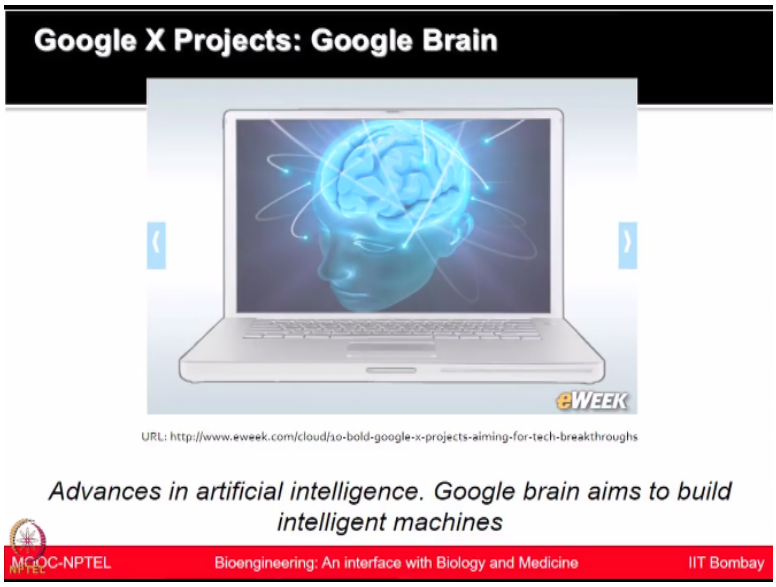
(Refer Slide Time: 06:29)



Many of you are engineering undergrads who wish to pursue a carrier which can be very attractive which can be cutting-edge and what you may have to think about in this era of 21st century, everything is you know really going to be transformed with the biology revolutions. So there is lot of you know integration from technology into the biological application which is currently going on and all your dream companies whether you talk about Google, IBM.

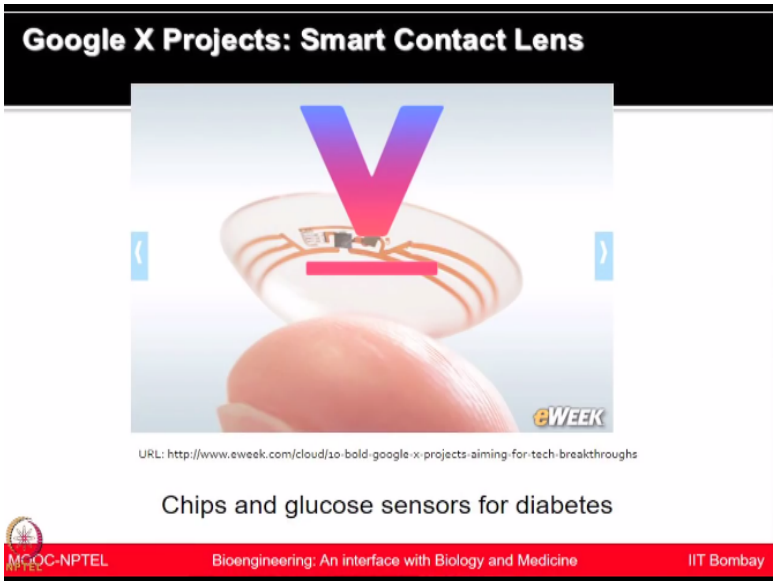
You think about all the big mega projects happening in these companies are actually now evolving with the biological applications.

(Refer Slide Time: 07:10)



So let us look at this particular project which is Google X project or the Google Brain. There is lot of you know research happening in the area of artificial intelligence. How to make the Google Brains which aims to build intelligent machines by incorporating artificial intelligence?

(Refer Slide Time: 07:26)



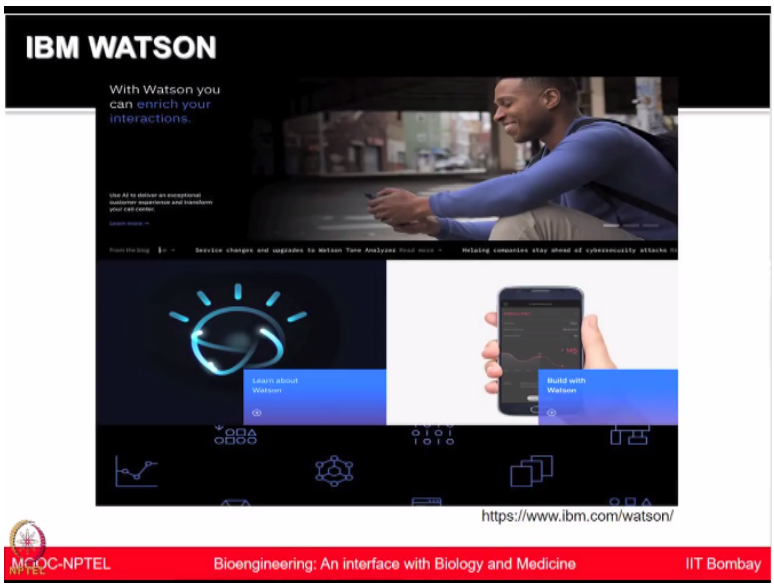
Even Google projects also incorporate the smart contact lenses. Just imagine that the contact lens if I remove the glass and I wear this you know contact lens and that lens has the sensors which could sense for the measurement of glucose and there are the chips which can monitor these glucose level throughout the day that data being recorded and being you know sent to

the mobile or sent to some other devices which could alert an individual that at which time you know there is a dip in the glucose level.

Because you know it is directly in the touch with the body fluid you are doing the real-time monitoring of glucose level and diabetes and you know many problems like this can be monitored in the real time manner. So these are kind of you know the very interesting projects which are happening at Google level of course there are many interesting other projects in biology.

But just to I am giving you flavor of various things which are ongoing in the area of technology and biology.

(Refer Slide Time: 08:27)



Another mega project is in IBM which is IBM Watson. They are using the supercomputing power again artificial intelligence and supercomputing in which way could be utilized to make a computer which could work if not better than human at least can think like human and then provide solutions to various medical problems and many other applications where Watson can be utilized to provide as the help and solutions.

So you can see that you know there are many these kind of you know latest projects which are biology driven happening in different you know major companies like Google, IBM, Microsoft, etc and these are just very few examples almost all the tech giants are currently focusing on in some other way different type of mega biological problems whether things are related to the healthcare issues or energy issues.

And many of these problems are currently undertaken which is on the interface of bioengineering.

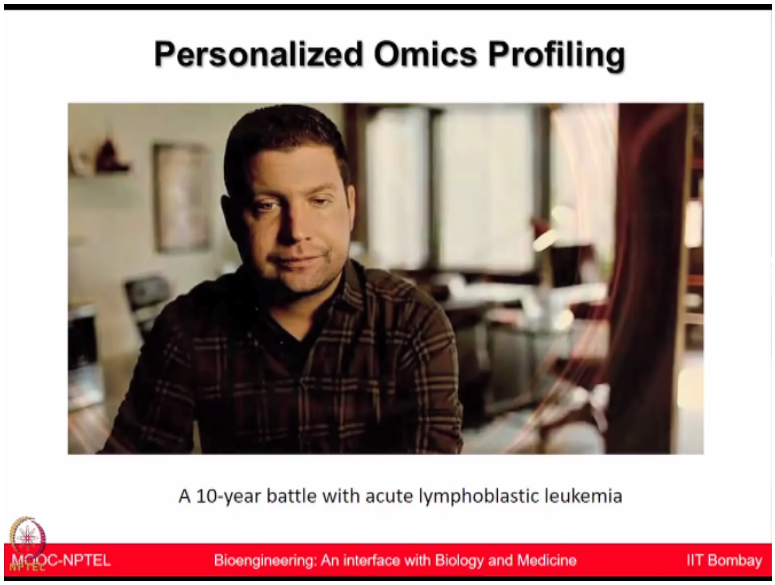
(Refer Slide Time: 09:27)

Another hand, there is lot of revolution is happening in the human genetics and medical research area. So you know several years ago in fact decades ago, the doctors used to prescribe medicine just based on certain biochemical parameter testing. Now things are really revolving very fast and the entire medical area is trying to evolve and try to incorporate understanding based on different type of gene and protein technologies, how they can provide some more accurate information.

(Refer Slide Time: 10:00)

So for example personalized omics profiling is one of the attractive area which is you know really ongoing and lot of revolutions are happening in this particular area where an individual's all you know body samples, different body fluids and bio specimens are analyzed a different type of by a molecular level to look at their DNA, RNA, protein at the omics level especially with the genomics, transcriptomics and proteomics technology and then trying to provide some sort of information which is unique for that individual.

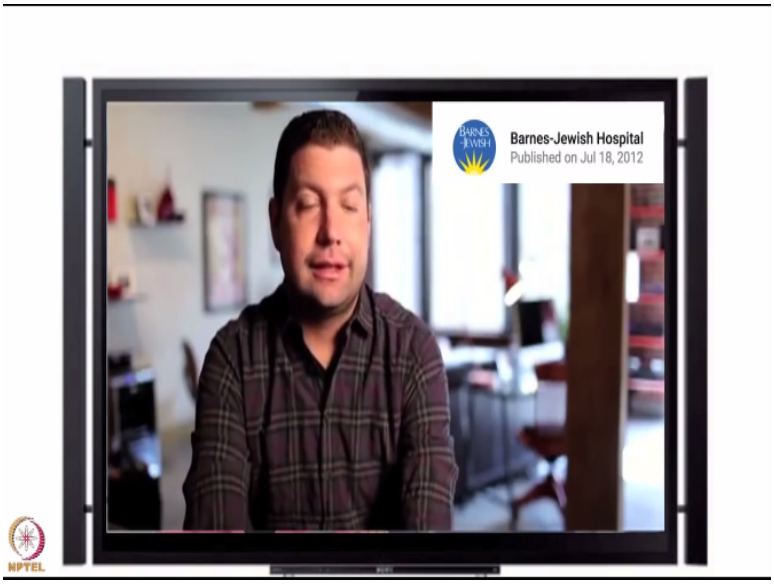
(Refer Slide Time: 10:31)



So in this slide I have shown you of an example from a Lukas Workman who was suffering from leukemia and after they identified that a specific mutation which is FLT3 mutation FMS-like tyrosine kinase 3 over expression is found in this particular in this case. Then, they are able to target a specific inhibitor axitinib which was actually approved by FDA for the renal cell cancer.

So just imagine that by knowing the what could be the cause for a disease if you can identify the right mutation right you know targets then you can provide more effective therapy. So this is one of the inspiring example in which the researcher could actually learn about his genome and then you know finally got some solution which could help to find very personalized medicine.

(Refer Slide Time: 11:20)



Actually during my last year of fellowship again I started feeling a little bit more rundown, it happened more suddenly this time, this past July I was diagnosed again with relapsed leukemia and was admitted into the hospital and started on very strong chemotherapy. Unfortunately, though the Leukemia did not go into remission after being treated with this very high dose chemotherapy. There were no real promising treatments on the horizon and so things looked rather bleak.

But at the same time as I was being treated my leukemia genome was being sequenced by the genome institute here at Washington University School of Medicine. We got back the sequencing results which showed that there were promising targets that were not even in the scope of our standard treatment protocols for this type of leukemia. Because of those results, I was able to start less aggressive chemotherapy that I could tolerate.

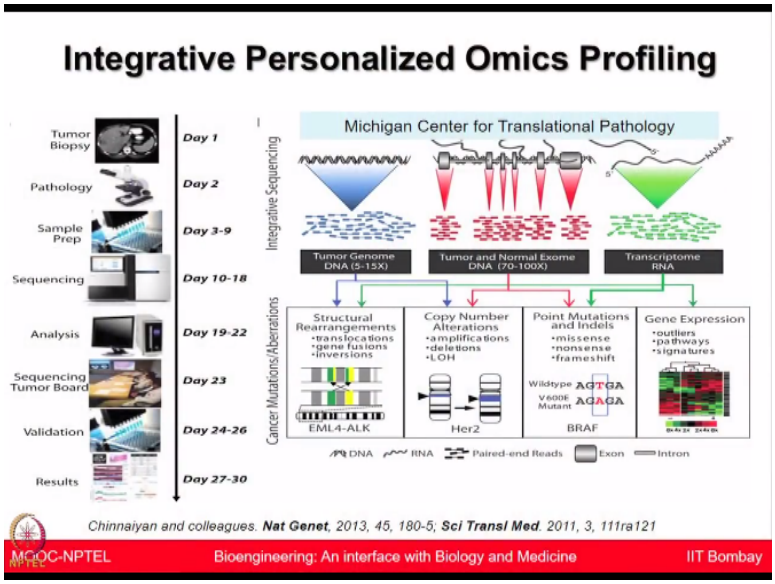
And then targeted therapy that had been approved for actually renal cell kidney cancer. Within a few days, my blood counts improved and within a few weeks my leukemia was in remission. So it is really going from a situation that looks really bleak to now a situation where there was hope again. There are more examples like this which is currently happening in the clinical area, integrative personalized omics profiling.

(Refer Slide Time: 13:03)

Dr. Mike Snyder from Stanford University in USA. He profiled his own body samples for you know almost 14 months and periodically analyzed in the longitudinal manner that what happens you know at different time interval the level at the you know protein level fluctuation, metabolite level fluctuation.

And those gave very novel inside that you know how the you know body can sometime get affected with different type of diseases and what kind of pathways could be changed in response to those.

(Refer Slide Time: 13:38)



Now you know various medical hospitals especially one shown here in the Michigan Center for Translational Pathology. They are using in a very systematic way of looking at both clinical and omics profile of individuals and then try to utilize that information to provide

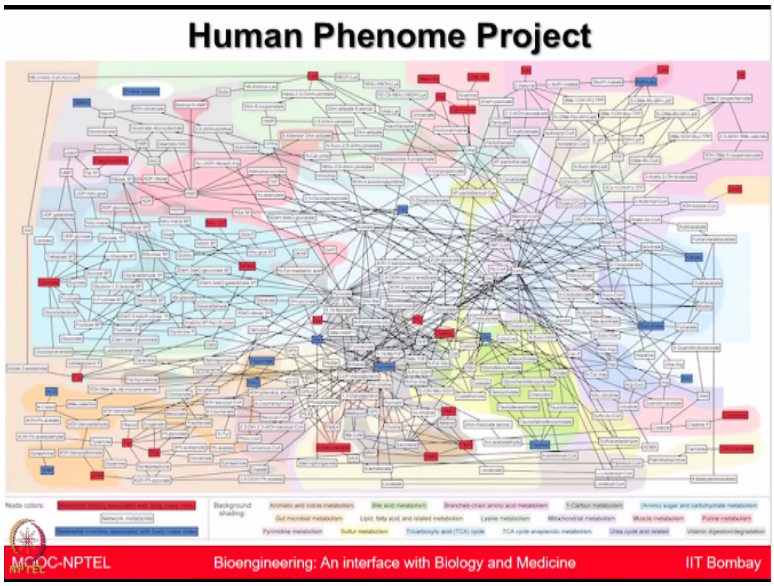
patients very personalized treatment Dr. Arul Chinnaiyan and his team has published many landmark papers in this area and which has shown elegantly that how understanding an individuals personalized omics profiling could be so helpful for the treatments.

You know other mega projects which are happening currently, intention is to look at what is maximum molecular changes happening in a given individual and to screen the similar things in large population.

(Refer Slide Time: 14:19)

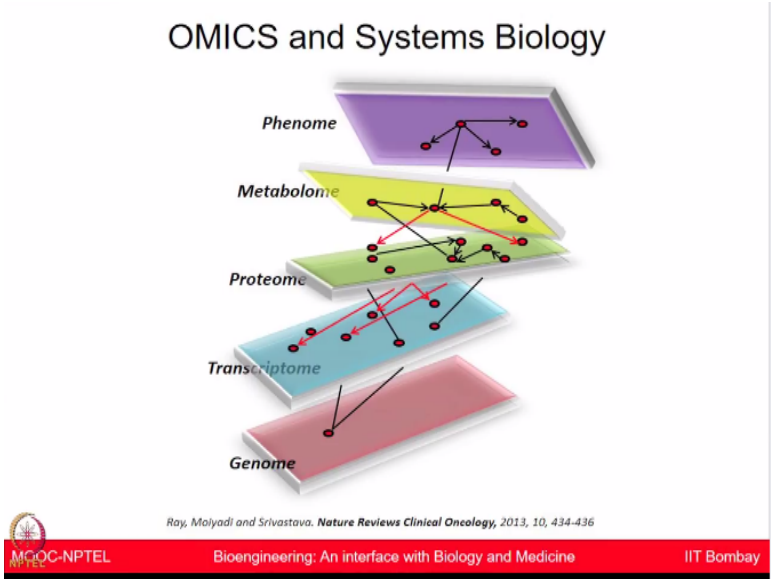
So the Human Phenome Project in London, they are looking at profiling all metabolites in healthy and populations affected from different diseases and trying to understand different type of you know metabolic networks which are being perturbed.

(Refer Slide Time: 14:33)



You know as there are healthy individuals acquire different diseases and those mega-projects you know being pursued at National Phenome Center which is now providing you know the very interesting and elegant publications and examples in which now we can understand the human physiology and human you know phenotypes by looking at both mass spectrometry and NMR based technology which is providing these kind of big data.

(Refer Slide Time: 15:03)



So the field which is emerging now is OMICS and systems biology where along with clinical information, information obtained at the gene level genome, transcript level transcriptome, protein level proteome, metabolites at the metabolome level and phenotypic behavior at the phenome level together integration of that could be very powerful. This entire field is generating so much large data set which comes under the big data.

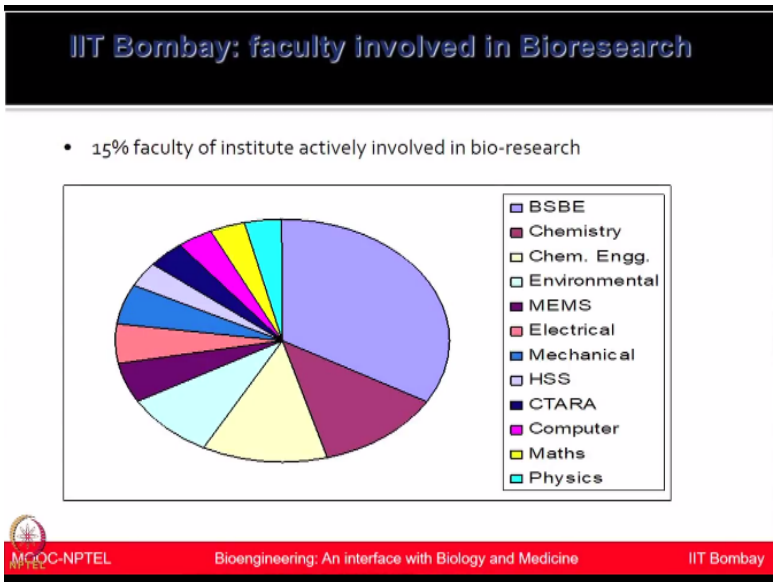
It requires lot of computational power, computational analysis which is again you know can be perceived by engineering undergrads like you students and how to integrate those information, build the models, create simulations and then use those information to predict the behavior of unknowns is being pursued by lot of computational engineers in the area of system biology.

So I hope that you know now you are getting the feel that in which way biology is getting integrated and applied with many disciplines and why it is you know so much important to integrate people from different disciplines together to bring the best minds to solve the major problems which requires integration of different skill sets. Now coming back to IIT Bombay where I am currently located.

(Refer Slide Time: 16:17)

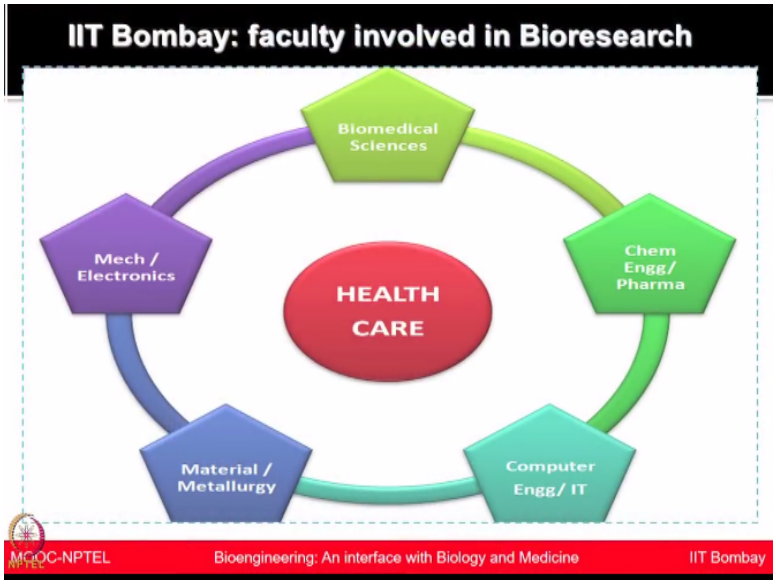
Bio-research is a reality at IIT Bombay.

(Refer Slide Time: 16:20)



Almost 15% of our faculty at IIT Bombay are actively involved in doing bio-research and wider spectrum is being covered from looking at the basic to applied and translational research. In fact, we did some sort of survey at IIT Bombay and found that you know not only the Department of Bioscience and Bioengineering is actively involved in doing bio-research.

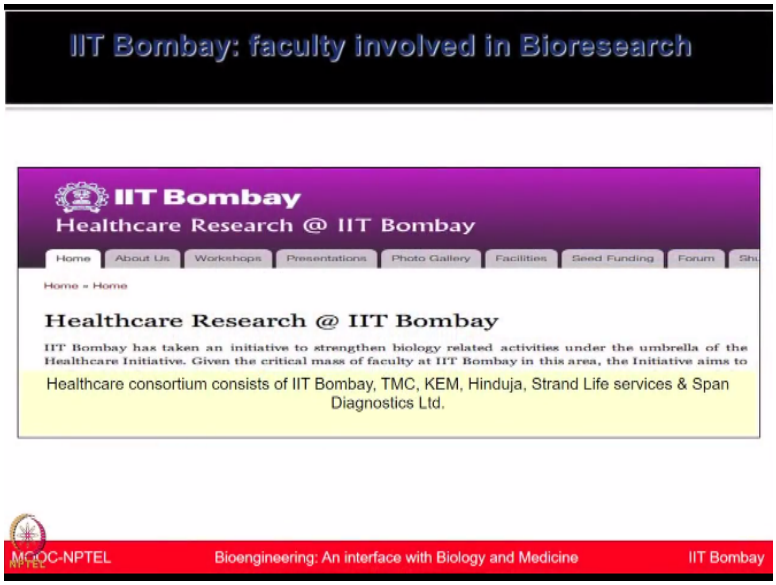
(Refer Slide Time: 16:42)



But many departments including chemistry, chemical engineering and even the departments like you know the (()) (16:47), electrical, mechanical, maths, physics and of course computer science. Many of these apartments are actively involved in the interface of biology and engineering and many applications of healthcare being perceived in these particular departments.

In fact, IIT Bombay working very closely with many surrounding hospitals which are providing a healthcare system.

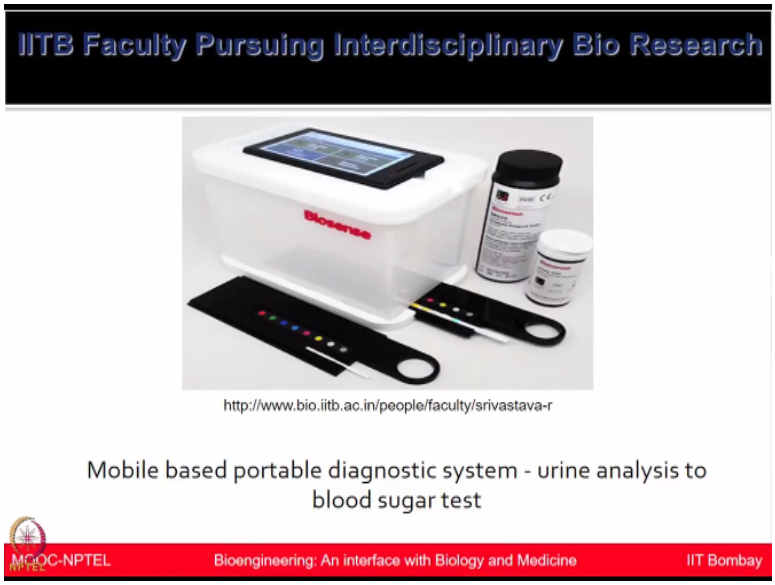
(Refer Slide Time: 17:13)



So we have a Healthcare Research Consortium at IIT Bombay where many local hospitals different you know pharma companies along with IIT Bombay faculty are involved to pursue many projects jointly. It just kind of gives you the feel that why you know there is this kind of

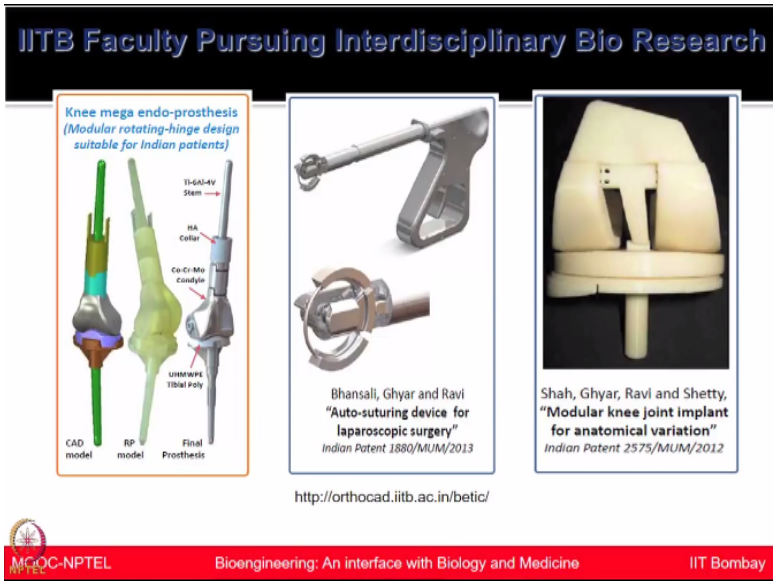
integration is required; it is only reality which is happening in our campus. Many of our faculty are from engineering backgrounds, some are from medical background, some are from basic science background, they are pursuing interdisciplinary bio-research.

(Refer Slide Time: 17:39)



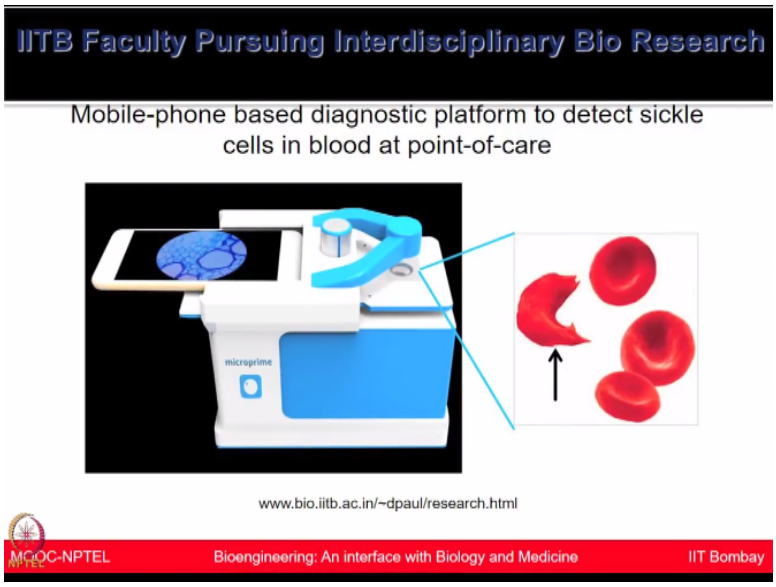
For example, shown here is one of the mobile based portable diagnostic system which has been used for urine analysis to blood sugar test. So again these kind of mobile based portable devices can be so handy and very useful.

(Refer Slide Time: 17:52)



Another lab at IIT Bombay they have developed different type of you know prosthesis devices which could be very quickly not translated to the actual you know clinical reality and many of the lab trials and the clinical trials are actually currently underway to bring these devices to the hospitals.

(Refer Slide Time: 18:10)



Few faculty members are also looking at mobile-phone based diagnostic platforms to detect sickle cells in the blood at the point-of-care diagnostic devices. Again you know many of these requires understanding of engineering solutions on one hand for the devices point of view and in the basic biological concepts which is required to know the exact problem and how to provide accurate solutions.

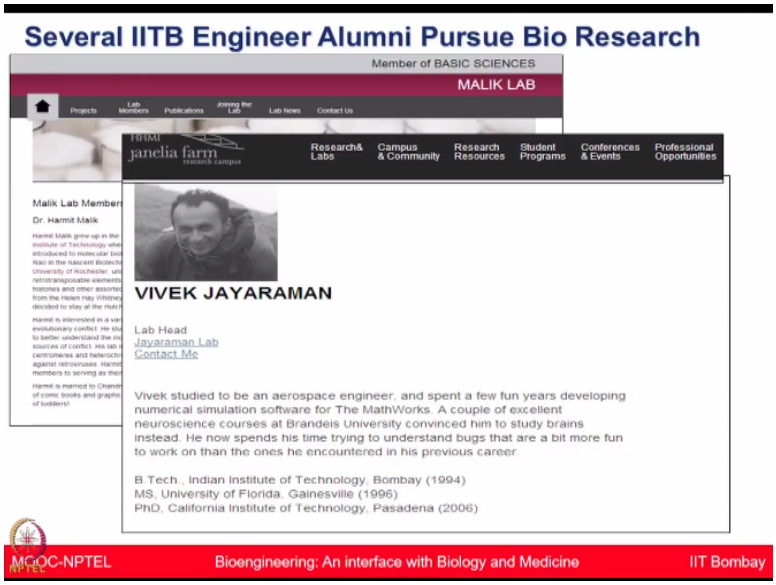
What will be you know motivating for you to learn that many students who learn biology at IIT Bombay even if they are engineering undergrads like you then eventually at you know you never know that you know one of the ideas spots your mind and you know at some point you might want to pursue that for your whole carrier. So there have been many students from IIT Bombay alumnae who moved to further pursue their carrier.

And then now they are faculty in different parts of the world which they are actually pursuing active bio-research again in the interface of bioengineering.

(Refer Slide Time: 19:09)

One shown you here is Dr. Harmit Malik. Again, he did some project from our department earlier and now he is at you know Fred Hutchinson Cancer Centre where he is looking into the you know various cancer related problems.

(Refer Slide Time: 19:25)



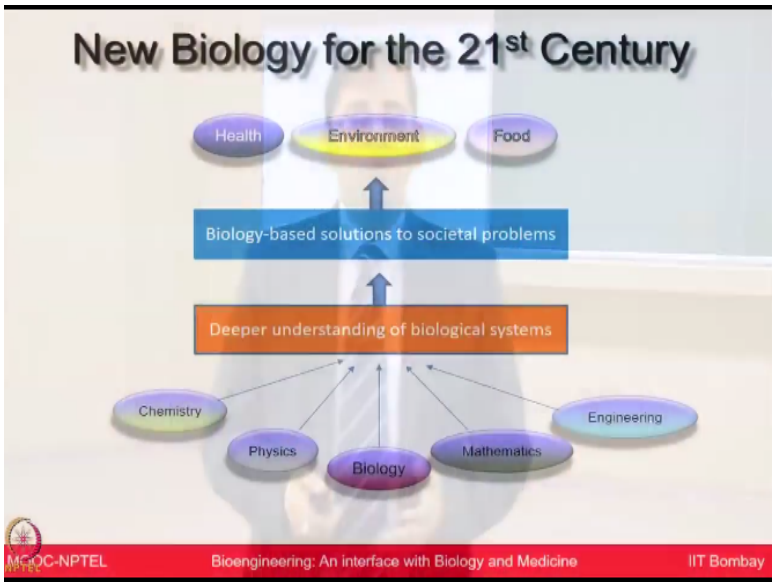
Dr. Vivek Jayaraman from Aerospace Engineering. He pursued in an active carrier in the area of understanding the brain behavior and thinking about the brain complexity in which way it can be utilized from the engineering point of view. Professor Chaitan Khosla, he is at the Stanford University of course you know he is one of the very esteemed, distinguished faculty and colleague for IIT Bombay who keep you know advising at IIT Bombay a different level provides mentorship.

And in one of the interactions he mentioned that every student of IIT Bombay all the undergrads should get the exposure of biology and that it just comes within vast experience looking at how the developments are happening elsewhere in whole world, you talk about you know Stanford, MIT Harvard, California, all of these you know big universities, they are pursuing active biology even for the engineering disciplines.

So therefore the integration of these two technologies can become very feasible, so therefore you know these are you know very nice example to convey you that in which way people who are having the active engineering carrier even they have brought in lot of biological solutions because of their you know basic understanding in biology. So in this course what we are going to talk to you is not the traditional biology.

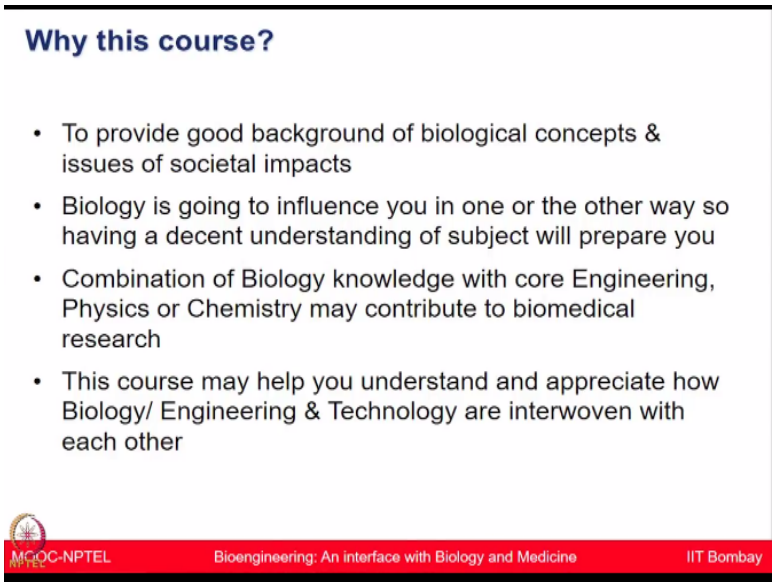
You know many times the biology requires you know mugging lot of terminologies, you have the complex word (()) (20:49) of those technologies those terminologies. So those things we are going to try to avoid. We are going to talk to you about a new biology which is required for the 21st century.

(Refer Slide Time: 20:59)



The new biology which will integrate chemistry, physics, biology, mathematics, engineering to deeply understand the biological systems and to provide biology based solutions to the societal problems which could be in the case of healthcare, environment, food and other disciplines. So again coming back why this course is required?

(Refer Slide Time: 21:26)



We want to provide you good background of biological concepts and issues which are relevant for the societal impacts. Biology is going to influence you in one or the other way. So it is important that you have a decent understanding of this subject which will prepare you well for your next set of carrier path. The combination of biology knowledge with core engineering, physics or chemistry may contribute to the biomedical research.

And this course may also help you to understand and appreciate how biology engineering and technology are interwoven with each other. So in the last two lectures, we try to emphasize you that why biology is required for engineers, why understanding the biological concepts and knowing it where it can be applied can be so immense value to you that you know it may spot some ideas in your brain which could be truly transformational in nature.

So we really want to talk to you about some of the basic concepts in the next lectures. At the same time while going through the basic concept I would like to emphasize about the actual applications in which way these could be utilized and probably many of the interesting interactions will also have with the clinicians who will try to post certain challenges, certain problems in front of you that why even doctors they need lot of engineering solutions in the medical practices.

So you know by combining the lectures some of the theoretical understanding, the interesting applications and bringing the clinician's perspective, we are going to make it more interactive, going to make it more motivating course for you and as we go along we will also

have the many assignments, quiz questions and interactions on the forum probably also some of the live laboratory demonstration sessions in the coming weeks. Thank you.

(Refer Slide Time: 23:19)