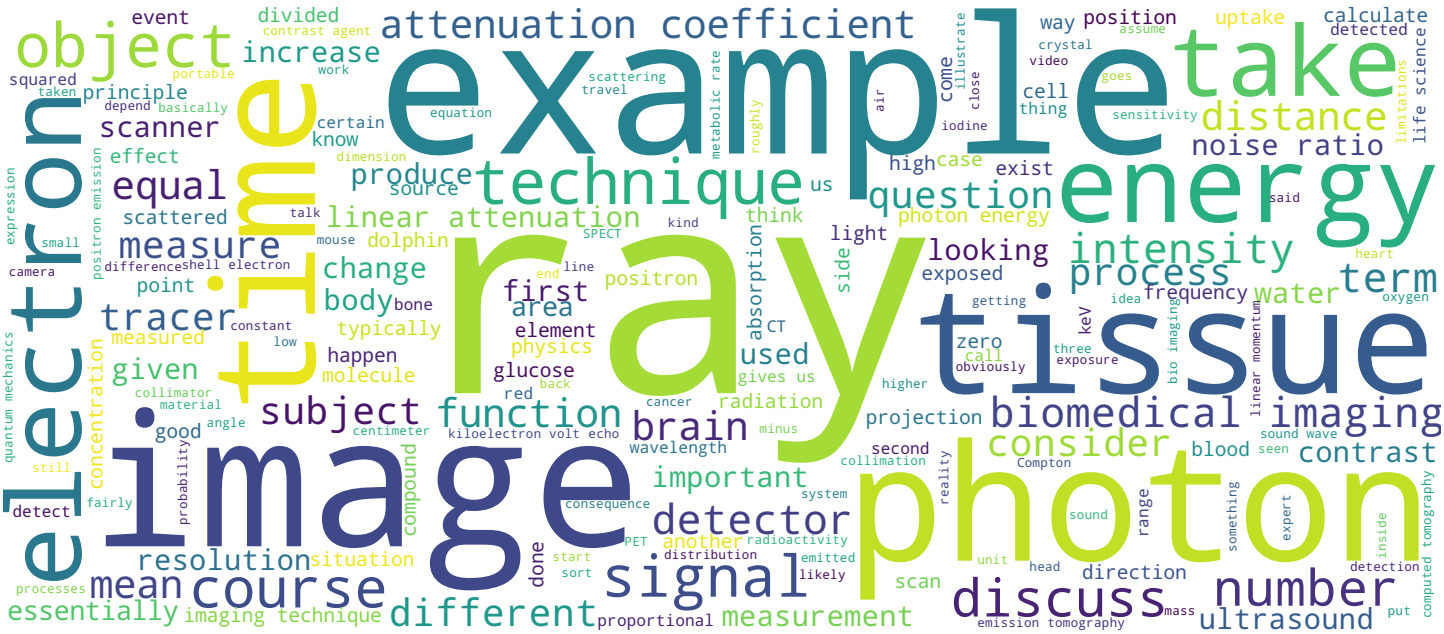
1.3 Importance of Biomedical Imaging

Fundamentals of Biomedical Imaging

Prof. Rolf Gruetter



EPFL

1-3. What is the importance of Bio-Imaging ?

Life Sciences are unthinkable without Bio-Imaging

Assessment of biological processes with **minimal** perturbation of the system

Examples:

Humans, animals,
cell/organ preparations

Modalities:

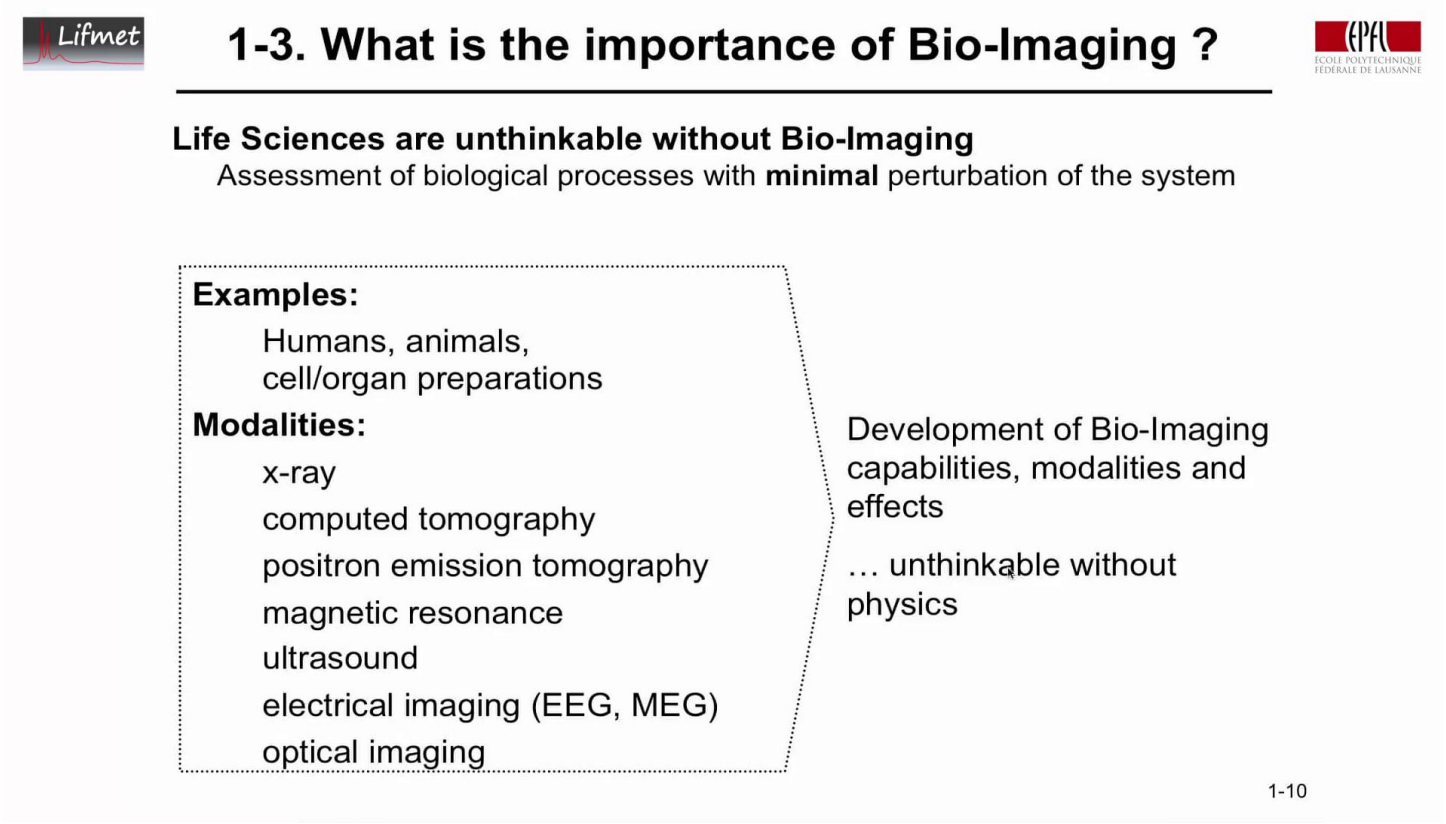
x-ray

We'll continue now with the question: What is the importance of bio-imaging? How important is this, really? Actually, nowadays life sciences, medical diagnosis or medical practice, both of them are unthinkable without biomedical imaging. One of the main features or contributions to this has been that we have a way to assess biological processes with minimal perturbation of the system. We can peer into the body, look at processes, and we do not have to go inside with any invasive means. Major discoveries in medicine have been done based on cadaver discovery or discoveries during surgery. Here, with biomedical imaging, it is completely non-invasive and without influence on the subject. We'll give you some examples. We have, in terms of applications, humans, animal research, it's also important to be minimally invasive, but also, sometimes it's cell preparations or organ preparations that one wants to study with biomedical imaging. What are the modalities that are often used? We have x-ray techniques. You've most likely been exposed to this technique, for example, a chest x-ray if you have pneumonia, dental x-rays, or if you have a fracture, computer tomography is derived from x-rays, is a more advanced way of imaging.

Notes

Summary

0m 04s



That one we will discuss. X-rays, simple x-rays, we'll not discuss in this course. Positron emission tomography, magnetic resonance. We have ultrasound for those of you who have been born in the last two to three decades. We have pretty much all been exposed to ultrasound technique in uterus, when we were fetuses, or if you are a parent, then your child has been exposed to ultrasound if you've had children, most likely, at least in the Western World. There's also electrical imaging measuring the electrical currents in the brain. That's EEG or MEG. Those techniques we will not discuss in this course. They are very distinct, and then there are, of course, also optical imaging techniques, that is using optical photons, visible photons, or infrared to image inside the tissue. Those techniques we will not discuss in this course either, mainly for the purpose of that here, in the the EPFL there are excellent-- --lectures treating just with these topics. And the key feature for this course is the element that these techniques, imaging techniques, bio-imaging capabilities, effects, contrast, etc. they are unthinkable without physics.

Notes

Summary

1m 48s

1-3. What is the importance of Bio-Imaging ?

Life Sciences are unthinkable without Bio-Imaging

Assessment of biological processes with **minimal** perturbation of the system

Examples:

Humans, animals,
cell/organ preparations

Modalities:

- x-ray
- computed tomography
- positron emission tomography
- magnetic resonance
- ultrasound
- electrical imaging (EEG, MEG)
- optical imaging

Development of Bio-Imaging capabilities, modalities and effects

… unthinkable without physics

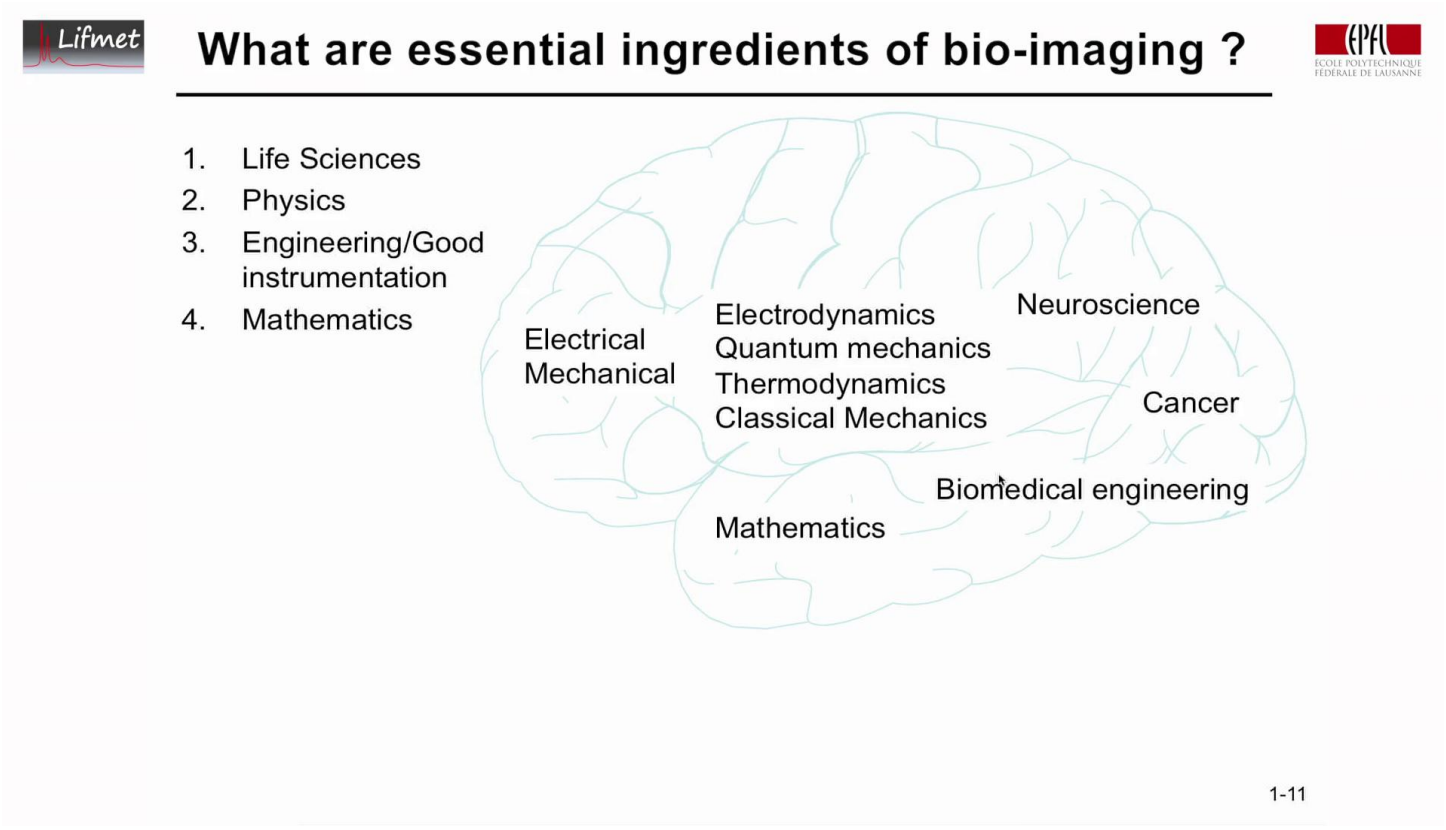
1-10

They are bio-physical processes that are deeply rooted in these techniques and we will discuss them, how these effects, how the construction of these cameras, these devices, how that influences signal-to-noise ratio, contrast-to-noise ratio, resolution, what kind of abilities we can deduce from these modalities.

Notes

Summary

3m 19s



So now, if we look at biomedical imaging, what are the things that we need in biomedical imaging. Obviously, we need life sciences. We need a living system. We need physics. And here in the course for life sciences, I will discuss primarily applications in neuroscience and cancer. I'll illustrate it mainly from these two sides. Now physics, the notions that in this course that we will make use of are electrodynamics, in particular, Faraday's Law, for example. Quantum mechanics-- we will not discuss quantum mechanics per se, but we are going to discuss a technique that's deeply rooted in quantum mechanics and that is magnetic resonance imaging. We have also thermodynamics considerations to consider, and also some elements of classical mechanics that we will be using from the physics. A good scanner with just life science and physics will not function. We need also for the techniques, we'll need good engineering, good instrumentation. We need electrical engineering, mechanical engineering, sometimes we need biomedical engineering to make these devices work optimally, and, of course, we need good mathematics. We've already dealt with the contrast-to-noise ratio with some elements of math that we need.

Notes

Summary

3m 42s

What are essential ingredients of bio-imaging ?

1. Life Sciences
2. Physics
3. Engineering/Good instrumentation
4. Mathematics
5. Chemistry

Bio- & organic chemistry

Neuroscience

Electrodynamics
Quantum mechanics
Thermodynamics
Classical Mechanics

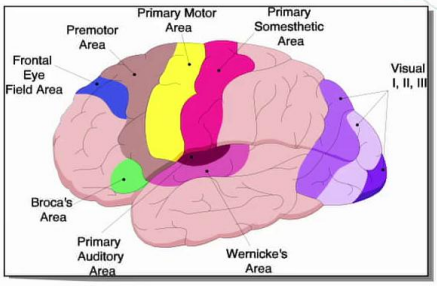
Electrical
Mechanical

Cancer

Multi-disciplinarity is important !

Biomedical engineering

Mathematics



1-11

We need good mathematics. And finally, in biomedical imaging, one also needs chemistry, and we will also discuss where chemistry comes in with contrast agents. We do not need to be experts in every one of the fields, but what is fascinating what brought me into this field is the ability to interact with such diverse disciplines to work really at the interface of all these different disciplines to learn from them, take what we learn from them, adapt them, take what we have in the needs in cancer and neuroscience, for example, how they impact instrumentation, the engineering, what we want to measure, mathematics, for example, or the compounds that we'd like to image the distribution to work with chemists on synthesizing those compounds or developing those compounds. That is what makes biomedical imaging a very exciting and interesting field to work with is to have all these interplays. Like I said, we do not have to be experts in every one of them, but we have to be willing to work at the fringe of our disciplines, and so multidisciplinarity, a willingness to engage one with another is important. And then, if we think about our brains, this is actually what our brain already does.

Notes

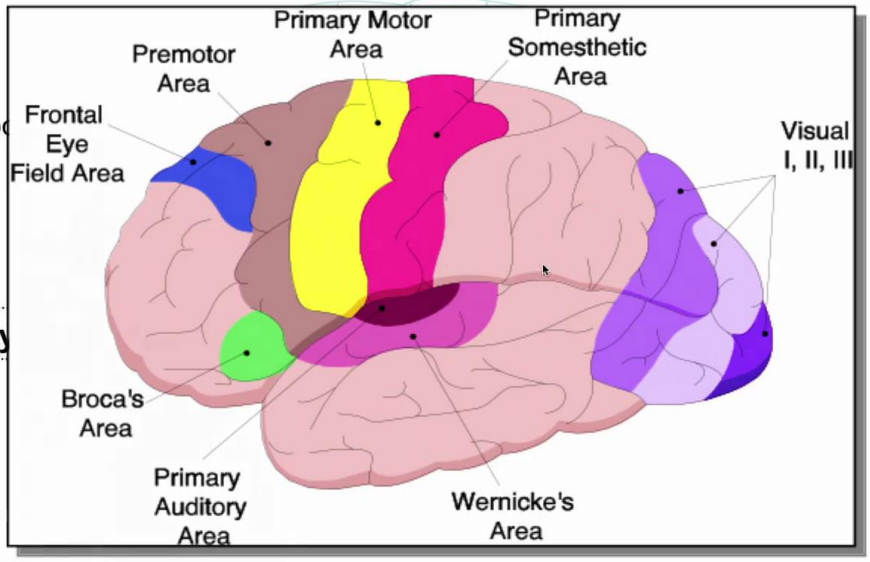
Summary

5m 10s

What are essential ingredients of bio-imaging ?

1. Life Sciences
2. Physics
3. Engineering/Goo instrumentation
4. Mathematics
5. Chemistry

Multi-disciplinarity



1-11

If we look at the brain organization, we have all sorts of brain areas that do different things. We hear here in Broca's area, we move our fingers in this area, we feel heat in this area, we see here in this area, we listen also here, and we process what we see here. So our brain and these areas are all simultaneously active.

Notes

Summary

6m 38s

What is the perfect imaging modality ?

1. Easy to use
2. Portable
3. Highly sensitive/good contrast

⇒ Does this exist ?

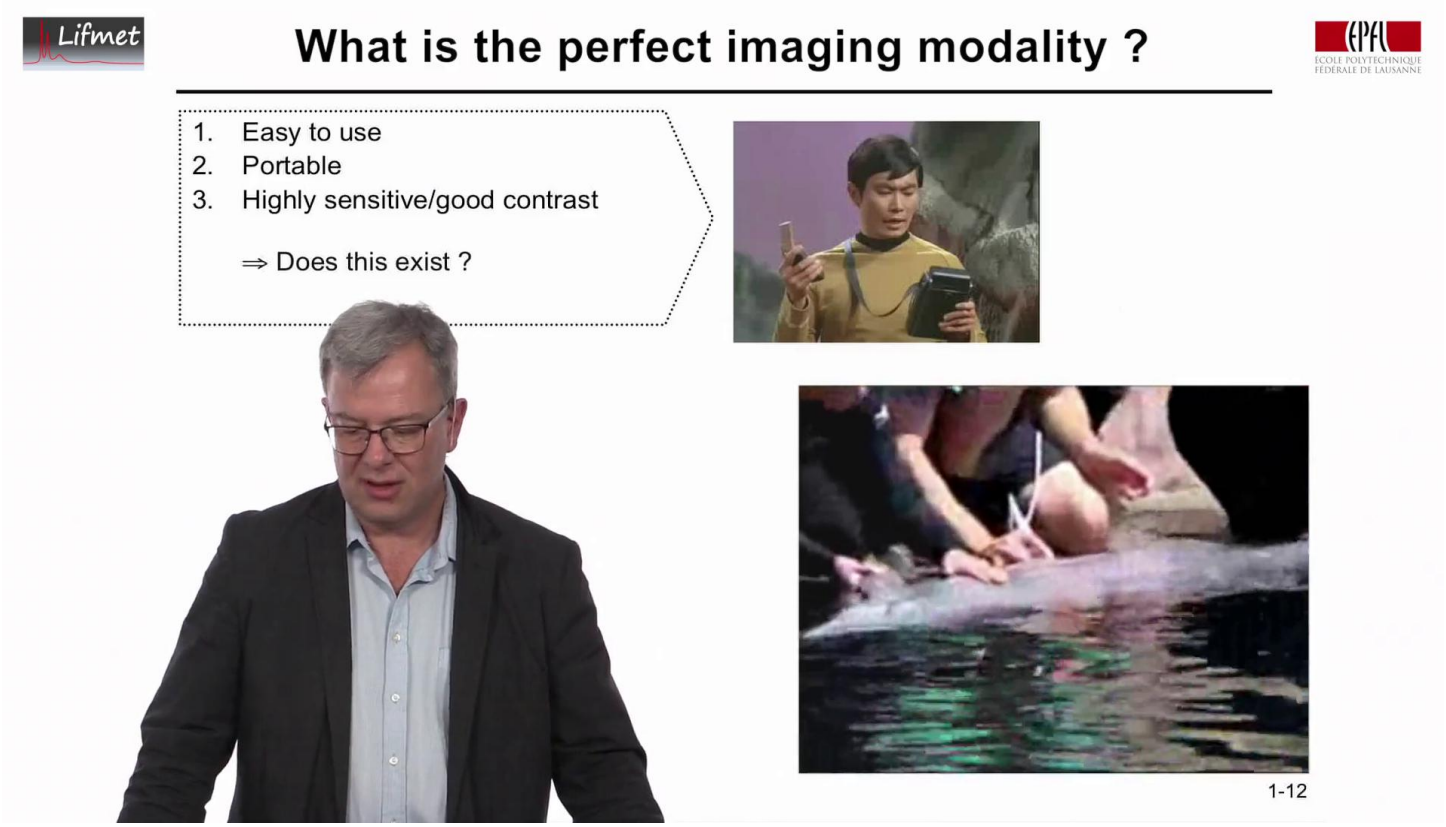
1-12

And so we can, of course, deal with all sorts of different disciplines having some insight in them, gaining some aspects, using aspects of them without being an expert in all of these techniques. So now here's a question, what is the perfect imaging modality? What would you like it to be able to do? Well, you want something easy to use. Here's an example. It should be portable. We have the example here again. And it should be highly sensitive and produce excellent contrast. Taking pictures of you or someone that you take a picture of with a camera here that's built in into the smartphone, that affords all that. Like I said, this is not an imaging technique for the intent of our course. We won't consider that, but in principle that's portable, I can take pictures. The question does this exist, something like this, like a cellphone, a smartphone camera, built-in camera, does that exist for biomedical imaging? In theory, it exists but not in reality. In Hollywood, it exists. You might recognize this gentleman here, if you look at the people appearing in here, what he's carrying in his hand is-- on the right side, is the equivalent of a smartphone communication device.

Notes

Summary

7m 00s



In his left hand he has what they call a tricorder. And a tricorder in *Star Trek* and the following series, they use it essentially, to diagnose you on 10 meters distance, they're able to diagnose whether you have some genetic alteration that you've been subjected to by exposure to an alien species. So in Hollywood, this kind of device called tricorder, the perfect imaging modality exists. It allows them to simply, rapidly diagnose without touching the subject to diagnose their disease even down to genetic diseases. Unfortunately, this does not exist for us, but here's an example which is very close, we are looking here at a video from a dolphin, and this dolphin is pregnant, has a fetus in it. And we have the doctor in this aquarium in Florida, he carries on the front of his head, he carries the output of the computed image, so the ultrasound image that's generated by a computer in real life and with his right hand he holds a transducer to the belly of the dolphin, so he's showing the images, and we can see the images here, the dolphin baby in the belly of its mother. The mother still stays in her natural environment, so it's still in the water basement. They're just holding her still.

Notes

Summary

8m 39s

What is the perfect imaging modality ?

1. Easy to use
2. Portable
3. Highly sensitive/good contrast

⇒ Does this exist ?

In reality,
every imaging method/modality
has its strengths and limitations

In this course you will learn to appreciate these and the reasons behind

1-12

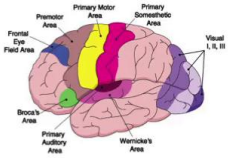
So this is fairly close to being a minimal invasive technique. It is easy to use, a person just holding it. It's portable. He went to the dolphin. And it provides decent sensitivity and good contrast. However, what we have to consider is that in reality, each imaging method or modality has its strengths and limitations. We can't have it all. Either they are strong on one side. They're able to depict one certain tissue feature, one technique and do it better than the other and vice versa. And we have limitations as well in the techniques. And the goal of this course is to bring closer to you an appreciation of these strengths and limitations of these techniques, and particularly the physical reasons that are behind it because there are physical reasons, the biophysical phenomenon or physical phenomenon that we are exploiting for these imaging techniques.

Notes

Summary

10m 11s

Credits



Lateral view of brain
http://brainmind.com/BrainLecture3.html

Star Trek *(video extract)*
CBS Studios Inc. - http://www.startrek.com

Dolphin Ultrasound with Dr Dold Vol 2 | SeaWorld® *(video extract)*
https://youtu.be/nTp5h1cFWjw

Notes

Summary

11m 20s