CHAPTER TWO

Introduction to the Medical Imaging system

Medial Imaging Throughout the Years

Before the 20th century if we wanted to know what was inside someone we needed to cut them open.

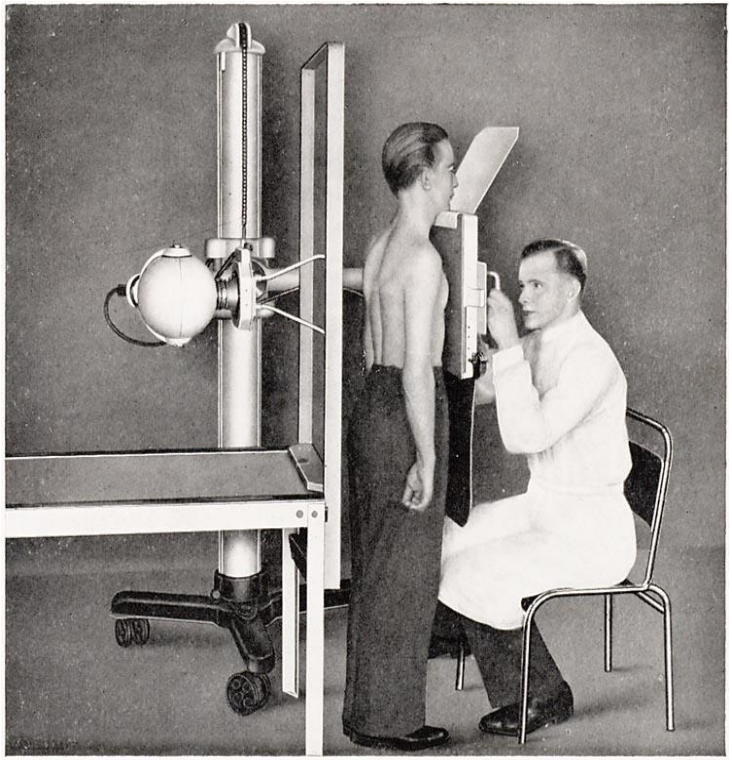
Usually done without any anesthetic or much masks or gloves

Medial Imaging Throughout the Years

Around 1900 Wilhelm Rontgen discovered the X-ray more or less by accident. He did not know what he had discovered, nobody did, but somehow these magical rays could see through many things including his hands.

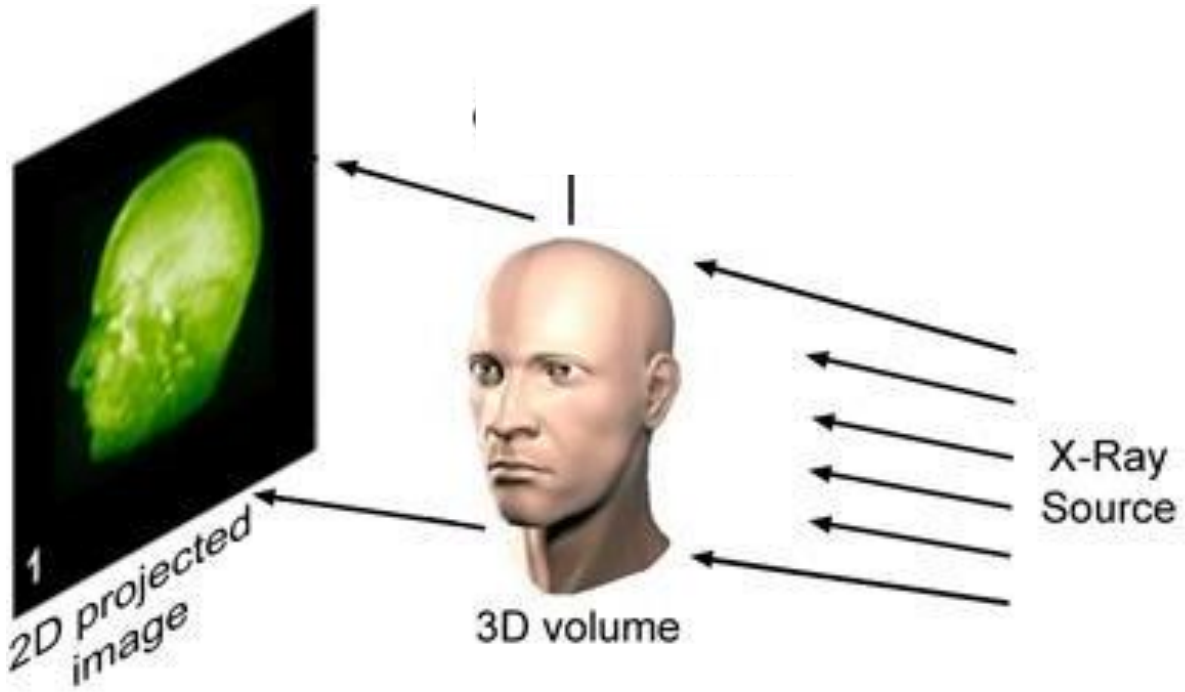
Wilhelm Röntgen

After a few decades, in which lots of people got sick from radiation exposure, we learned what x-rays were, we learned how to limit the x-ray dose and we learned how to take useful medical images safely.



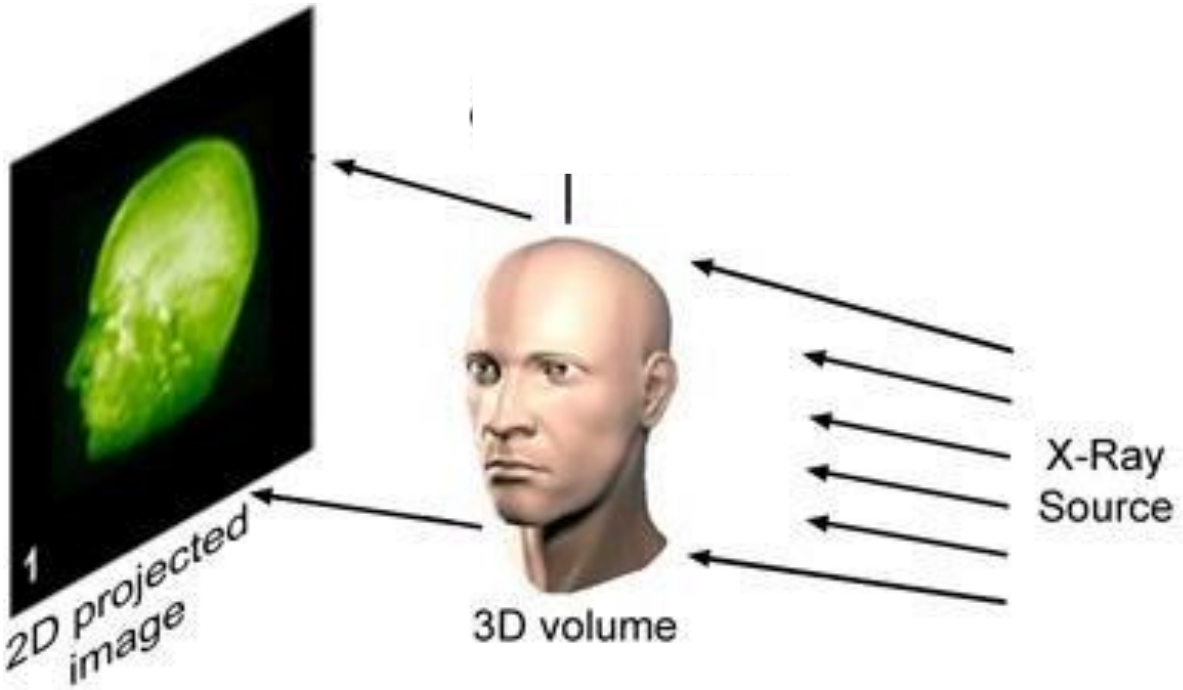
Medial Imaging Throughout the Years

This first imaging method is called projection x-ray or projection radiography. It was a huge boom to medicine. For the first time we could look into a persons body without cutting them open.



Medial Imaging Throughout the Years

However, there was still a problem! Projection x-ray produced a projection or shadow of the x-rays as it travels through you. All depth information is lost! Useful but not as useful as it could be!



Medial Imaging Throughout the Years

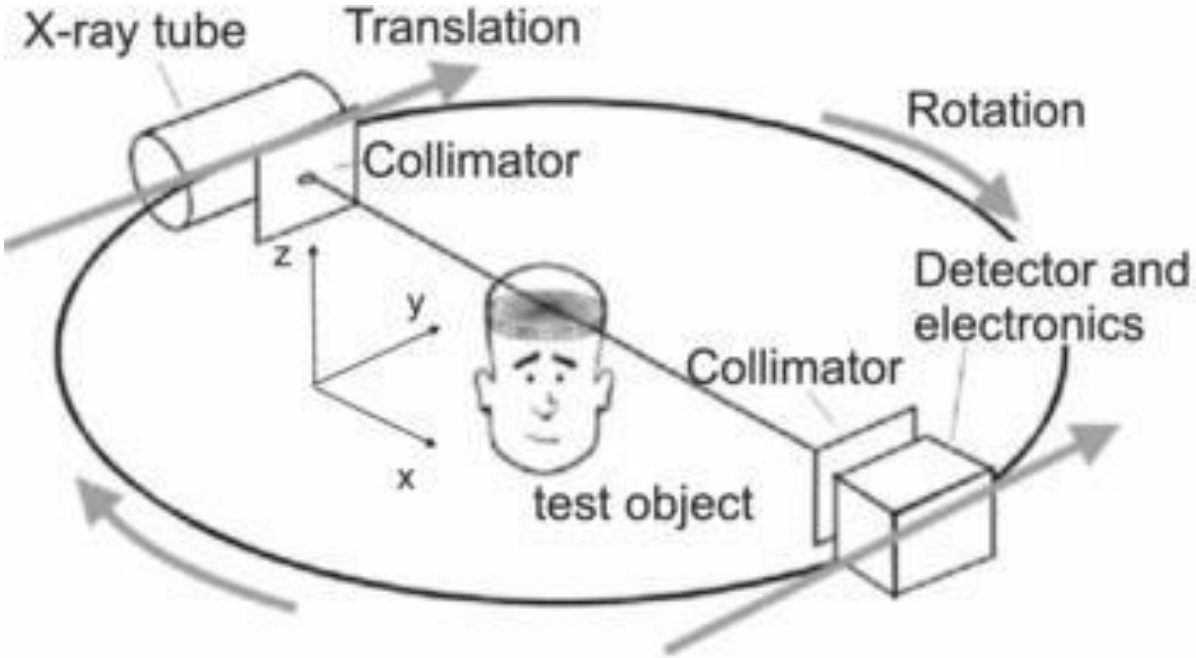
Enter Hounsfield and Cormack in the 1960's with a really big idea!

Godfrey N. Hounsfield

Allan M. Cormack

Medial Imaging Throughout the Years

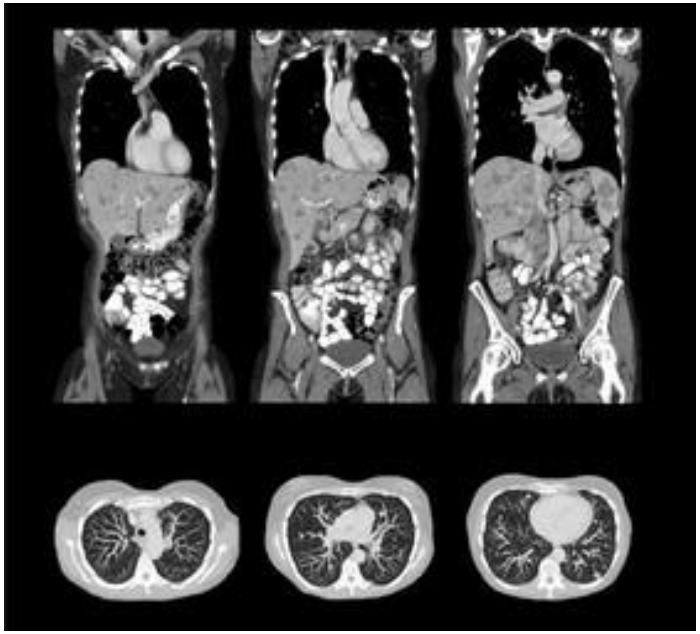
Enter Hounsfield and Cormack in the 1960's with a really big idea!



If instead of taking a single projection x-ray image what if we took lots of them at different angles looking through someone?

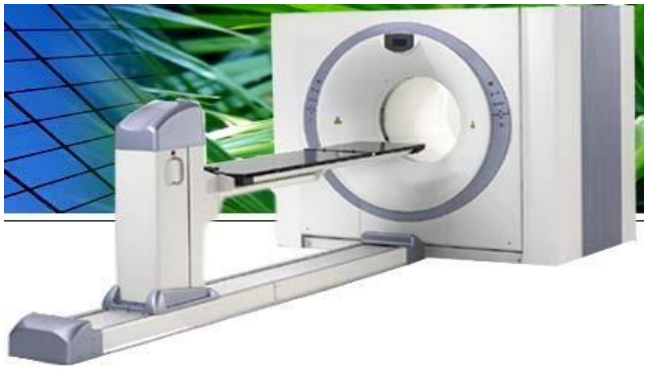
Medial Imaging Throughout the Years

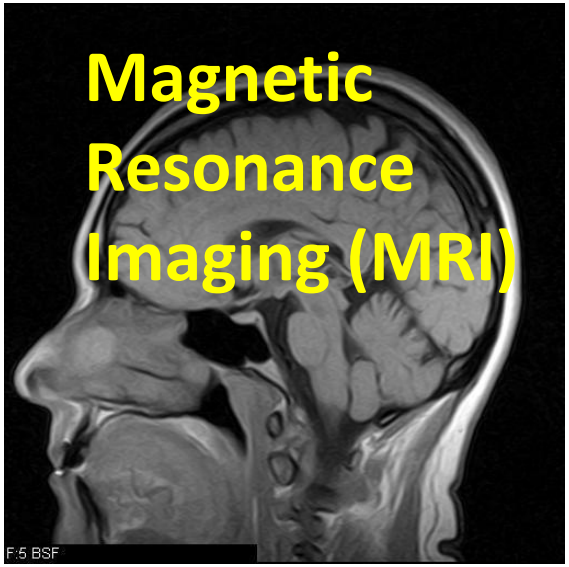
If I used the computer, pretty new idea concept in 1960s, would this be enough information to reconstruct a 2D slide of you?

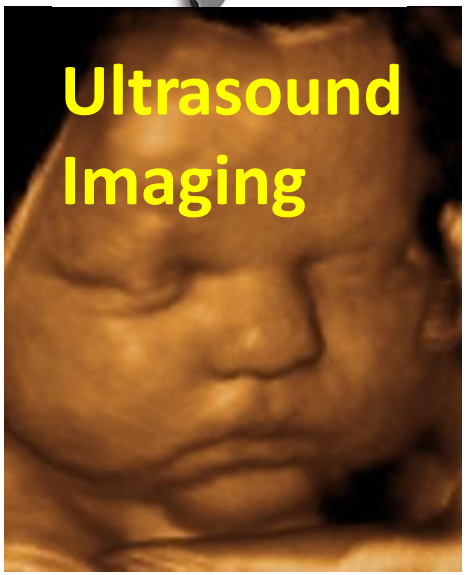


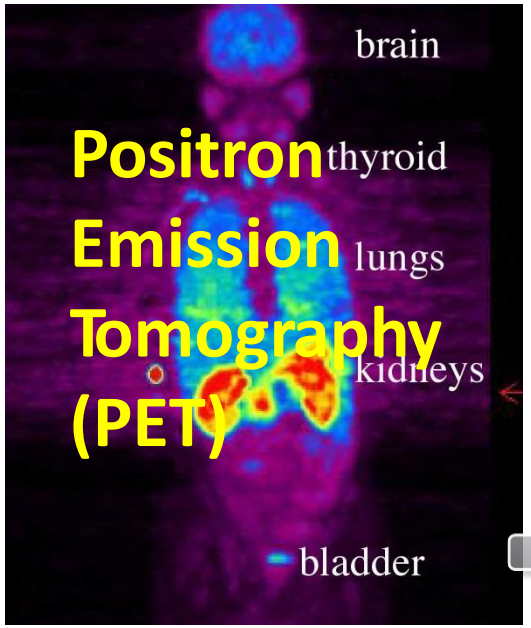
Of course this worked! It is now called computed tomography (CT) and has saved countless lives. It also won Hounsfield and Cormack the 1979 Nobel Prize in Medicine.

The success of CT began a revolution in computer based medical imaging systems (or tomographic systems).







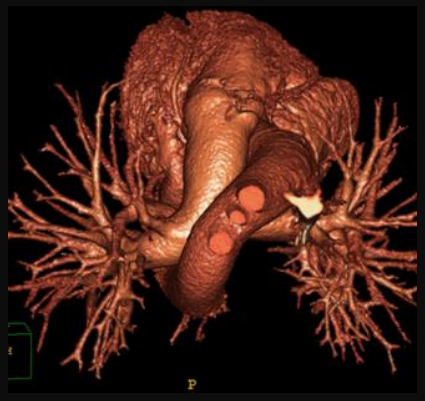


Why do I love this course?

Two reasons:

(1) Medical imaging brings together a bunch of topics you have learned so far in a useful and elegant way. The subject combines physics, instrumentation, signals and systems, computer science, math, physiology, biology, and medicine for one noble purpose.

(2) There is just something magical about it!

What is an Imaging System?

I think an imaging system is simply a device that tries to represent a spatial representation of some property (or properties) of an object or objects.

Lets look at some examples and try to use this definition to describe the imaging system.

What is an Imaging System?

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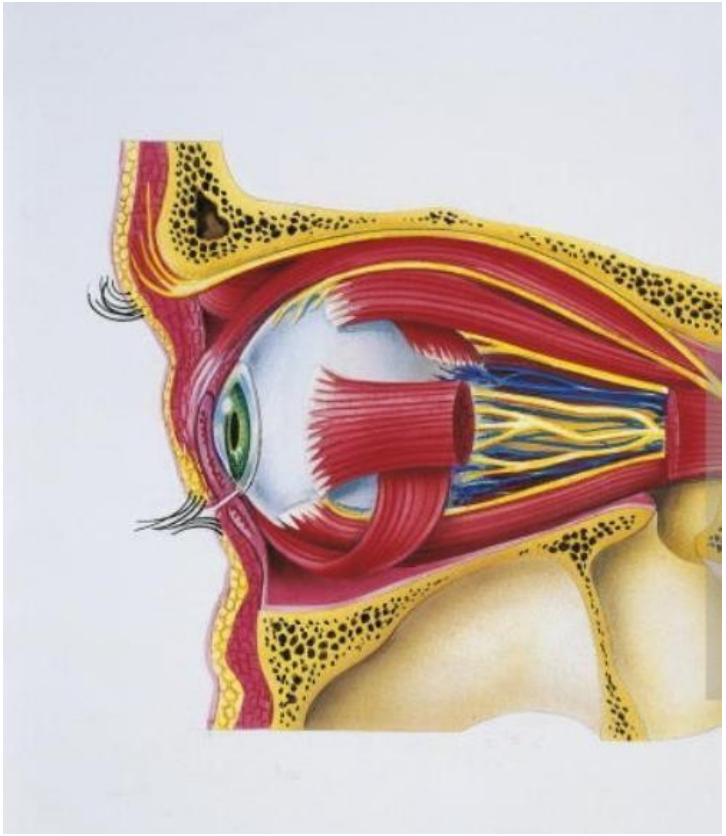
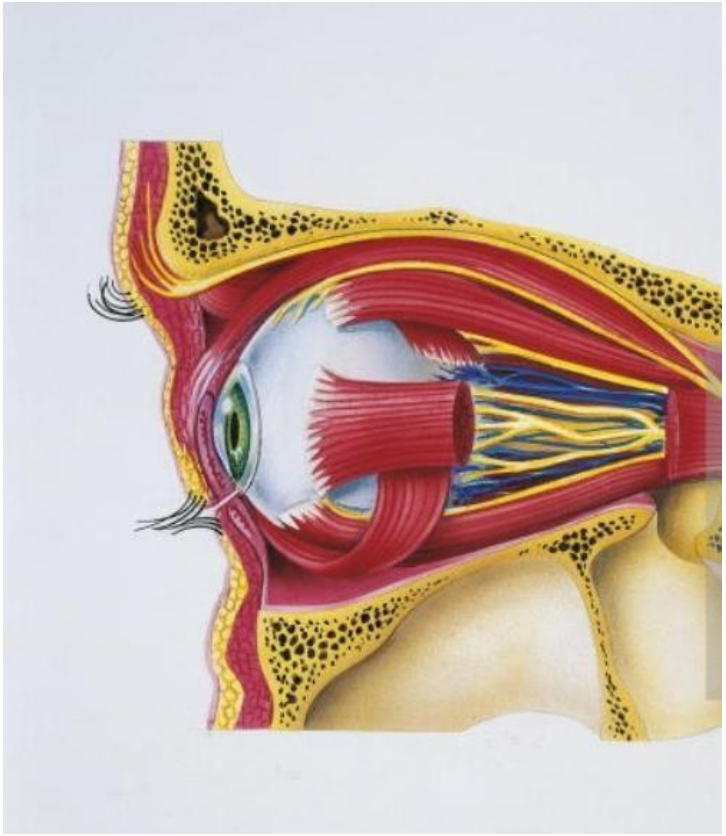


Question: What properties of an object or scene does our human visual system try to spatially represent?

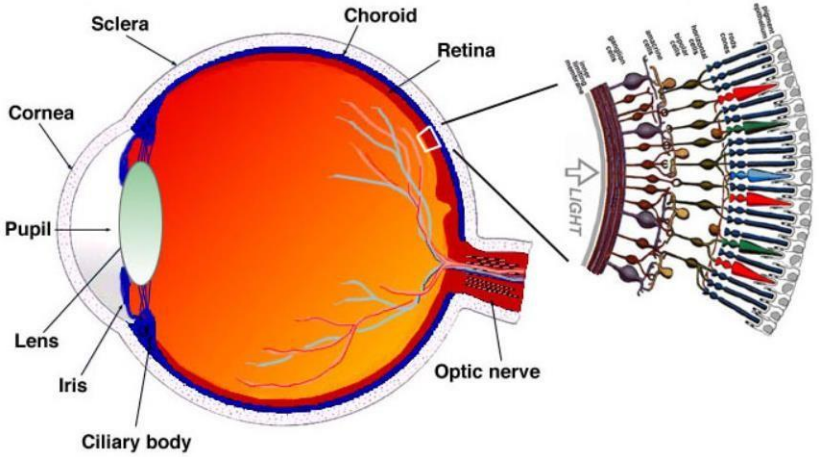
A: The spatial and spectral reflectance, transmission and absorption of light within the visible portion of the EM spectrum (430–790 THz)

What is an Imaging System?



Q: What spatial representation of that property does our human visual system use?

A: 2D spatial distribution of electrical impulses on the rods and cones of our eye. Those signals are transmitted to the brain and processed to create what we see.



What is an Imaging System?

Q. What properties of an object does an infrared camera measure?

A. It measures the spatial distribution of infrared energy emitted from an object due to it's temperature. The typical spectral bands have wavelengths 1 to 2 micros, 3 to 5 microns and 8 to 12 microns.

What is an Imaging System?

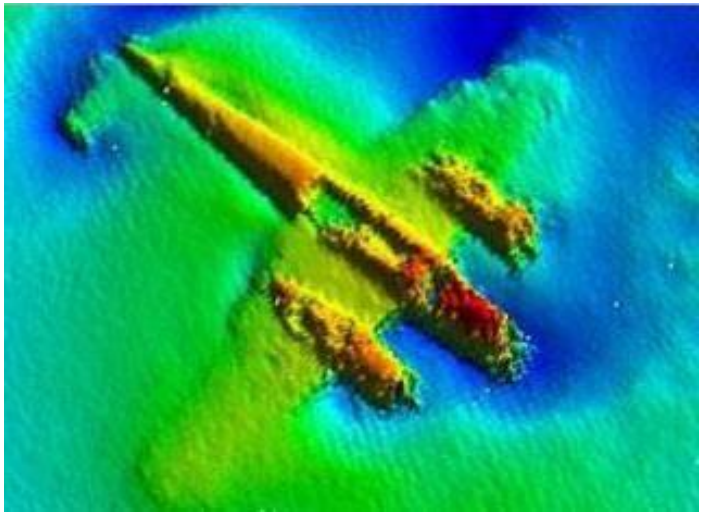
Q: What spatial representation of that property does a thermal camera use?

Infrared Camera

A: The integrated thermal energy from a 3D object is converted to electrical signals on a 2D detector array and then processed into an image by the backend electronics.

What is an Imaging System?

SONAR Image



Q. What properties of an object does a SONAR measure?

A. It measures the reflectance of a pulse of high frequency sound waves.

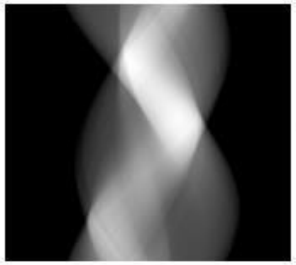
What is an Imaging System?

	What property does it image?	How does it represent an image?	Is this passive or active imaging?	Advantages?	Disadvantages?
Human eye	Reflectance of light in the visible portion of the EM spectrum	2D representation of electrical impulses in the retina	passive	• good resolution • good contrast • lots of illumination (sun)	• needs external illumination • can't see through much
IR Camera	Emission of light in the infrared portion of the EM spectrum do the temperature	2D array of pixels in a IR detector array (focal plane array)	passive	• decent resolution • temperature based so you can see at night • can be used to distinguish between different chemicals (spectroscopy)	• relatively poor contrast (depends on difference in temperature). • can't see through much • hard to see far away
SONAR	Reflectance of pulses of high frequency sounds waves	2D or 3D table of numbers found by scanning the sonar beam	active	• works underwater • good contrast between hard and soft • 3D	• relatively poor resolution • lots of things look the same • does not work out of water (or stuff that is like water).

Overall Concept

object

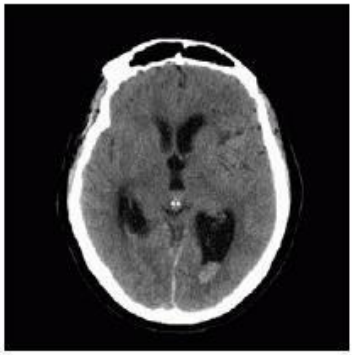
imaging device



data

imaging algorithm

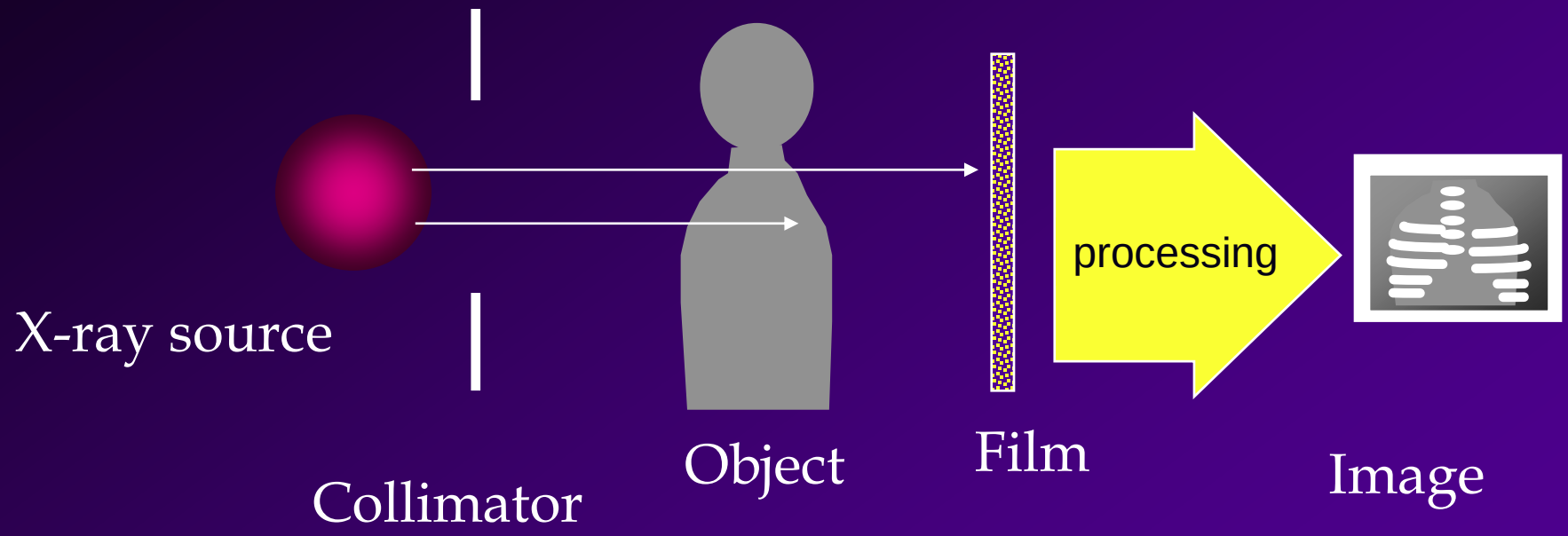
reconstructed cross-sectional image



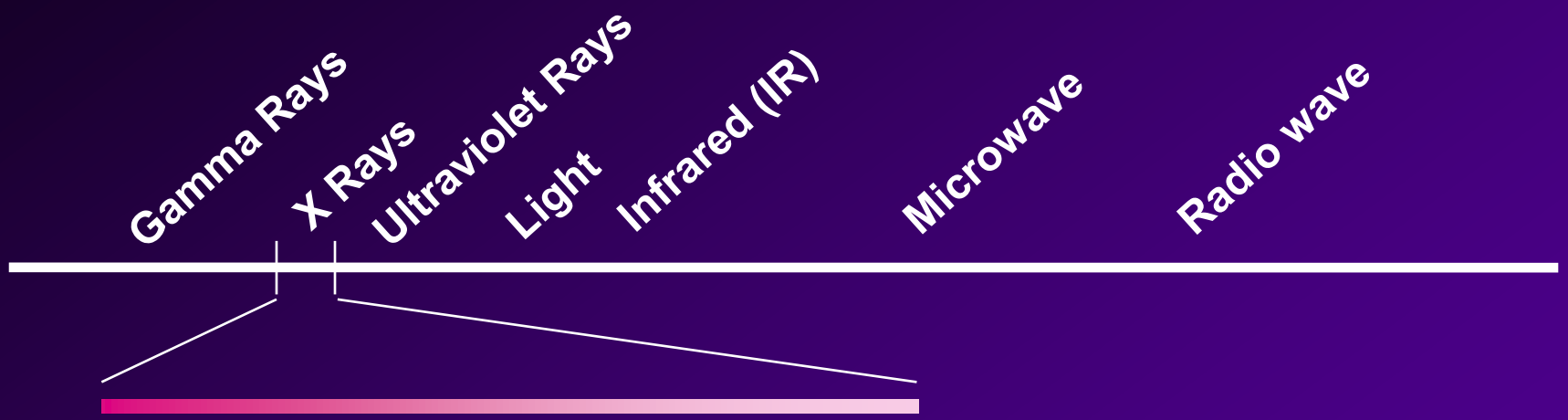
Medical X-ray Systems

- Chest **x-**rays (Abnormalities in lungs, heart, other abdominal organs, broken ribs)
- Mammography (Calcifications/abnormalities in breast tissues)
- Dental x-ray (Cavities, wisdom teeth)
- Others include detecting broken bones.

Typical Imaging Chain for Medical X-ray Systems



X-Rays

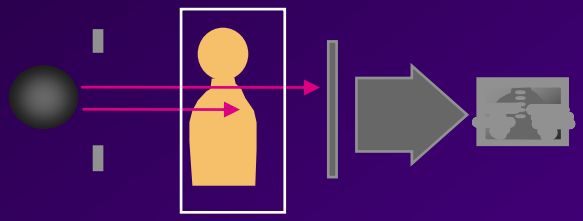


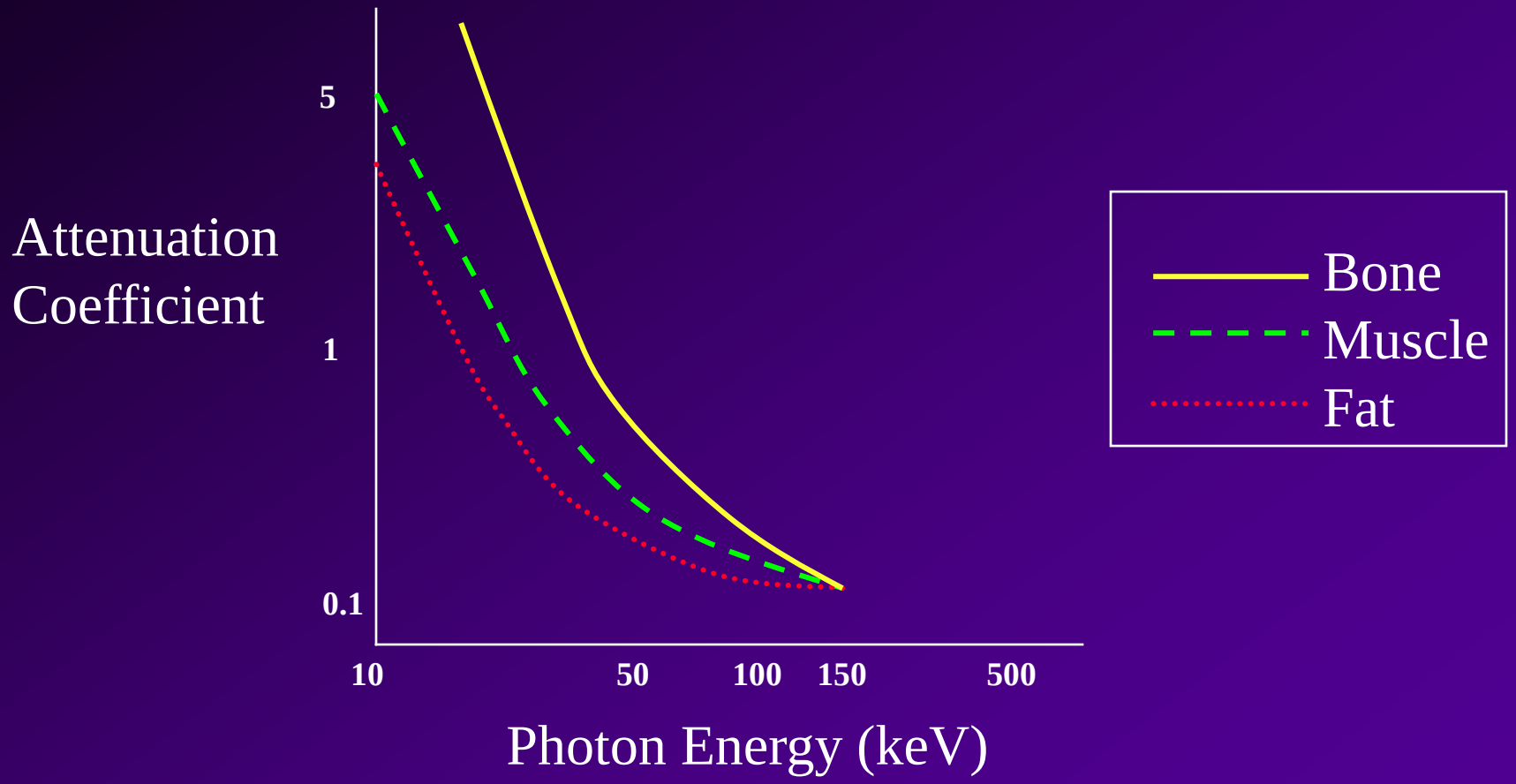
- Usually detected as particles of energy (photons).
- Discovered in 1895 by Wilhelm Conrad Roentgen.

Object

- What can happen to an X-ray when it encounters the object to be imaged?
  - *Passes* right through the object.
  - *Absorbed* completely by the object.
  - *Scattered* by the object

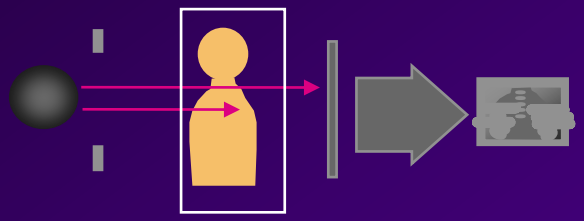
Attenuation Coefficient





Attenuation coefficients tell you the “x-ray blocking power” of a material.

Attenuation Coefficient



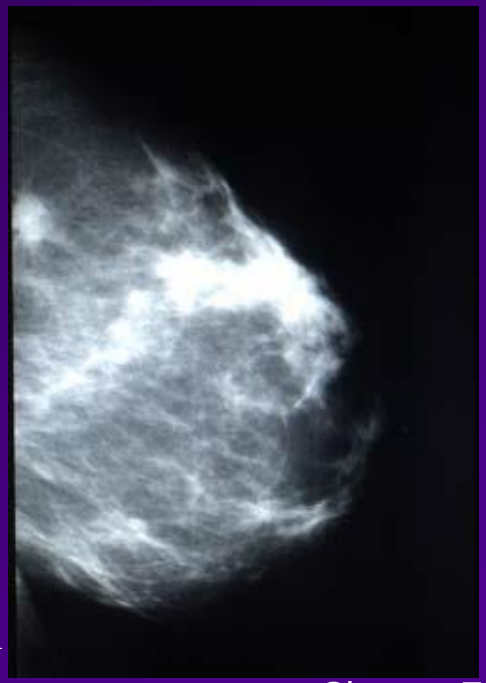
- Coefficient depends on the property of the material.
  - Density (Bone has a high density compared to soft tissues)
  - Chemical Make-up (Lead blocks x-rays; lead screening used to protect patient & technicians)

Detector

- A special photographic film is used to capture the x-ray photons which passed through the object.
- The film is then processed.
- Film turns dark where it was exposed to x-ray photons.

Typical X-Ray Images

X-ray image of hand



Mammogram

Dental X-ray

Image Quality Factors

- Source
  - Energy of the photons
  - Collimation
- Object
  - Attenuation coefficient
  - Source-object geometry
- Detector
  - Object-detector geometry
  - Efficiency

Advantages of Standard Diagnostic Medical X-ray Imaging Systems

- Readily available
- Reasonably cheap
- Simple systems to maintain
- Many experienced and trained personnel due to the fact that technology has existed for a while

Disadvantages of Diagnostic Medical X-ray Imaging Systems

- Exposure to harmful radiation.
- Not much contrast between different soft tissues.
- Image is a shadowgram (projection image) with no depth information.