

# Medical imaging

X-rays

X-ray  
radiography

X-ray tomography

Computed  
tomography

Magnetic  
Resonance

Ultrasound

# X-rays

- 1895



Wilhelm Roentgen

Philipp Lenard

X-rays

X-ray  
radiography

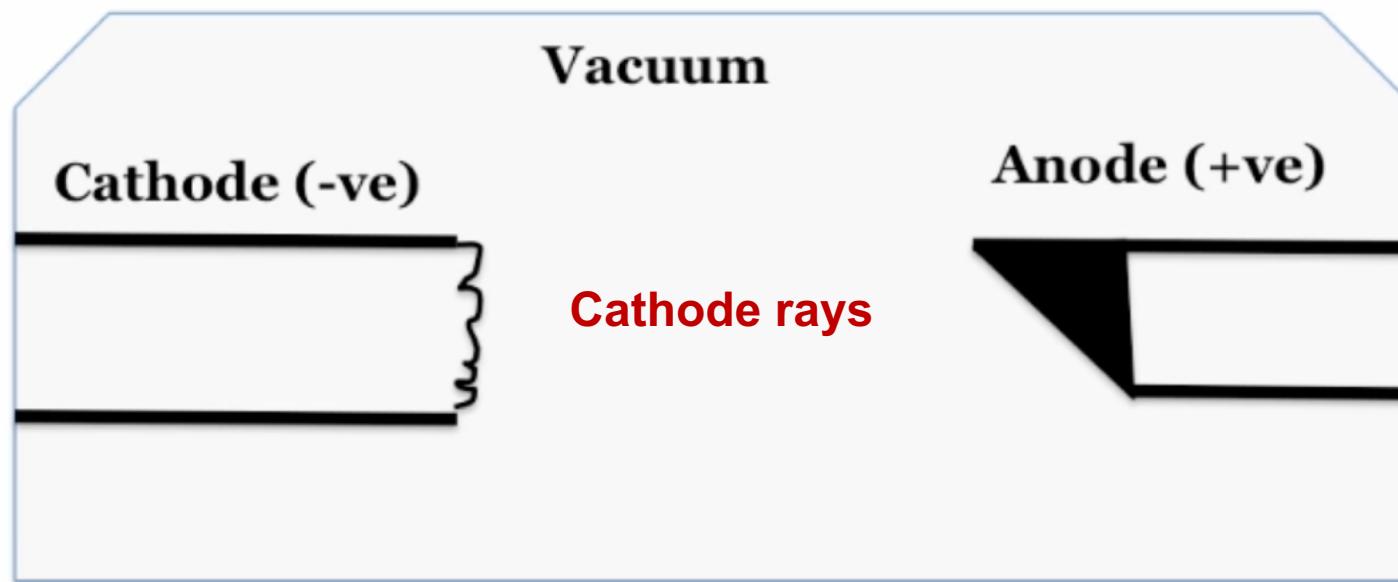
X-ray tomography

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# X-rays



- <https://www.youtube.com/watch?v=QTO6HolfqKw>

**X-rays**

X-ray  
radiography

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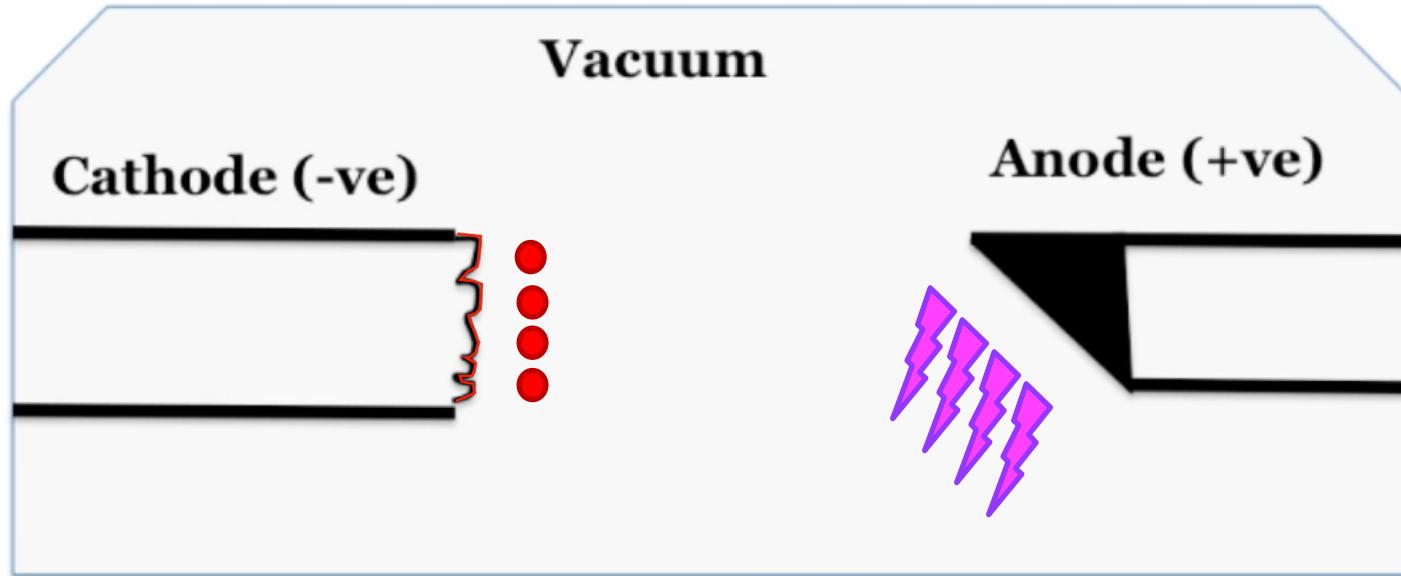
Magnetic  
Resonance

Ultrasound

# X-rays



iHeartCraftyThings.com



Fluorescent  
cardboard

X-rays

X-ray  
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# X-rays

Electromagnetic wave of **high energy** and very **short wavelength**, which is able to pass through many materials opaque to light.



X-rays

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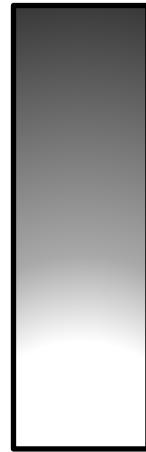
Magnetic  
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# X-ray radiography

5 densities:

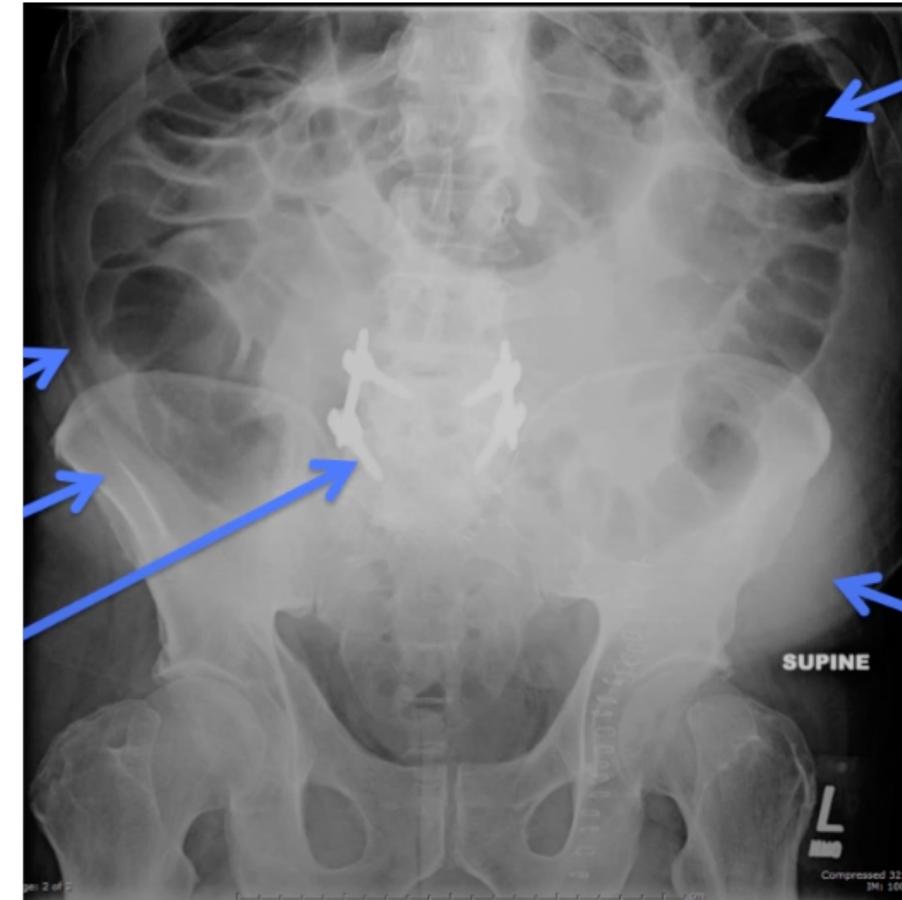
- Air
- Fat
- Fluid and soft tissue
- Bone
- Metal



Right

Superior

Left



Inferior

X-rays

## X-ray radiography

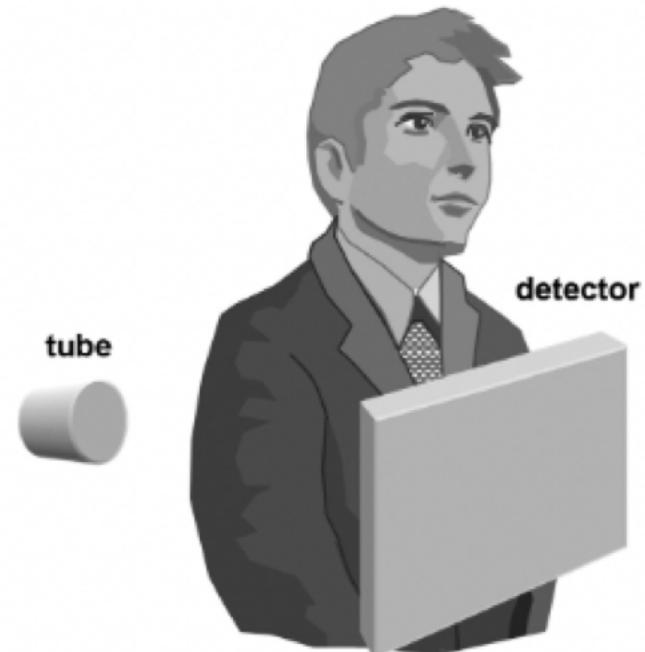
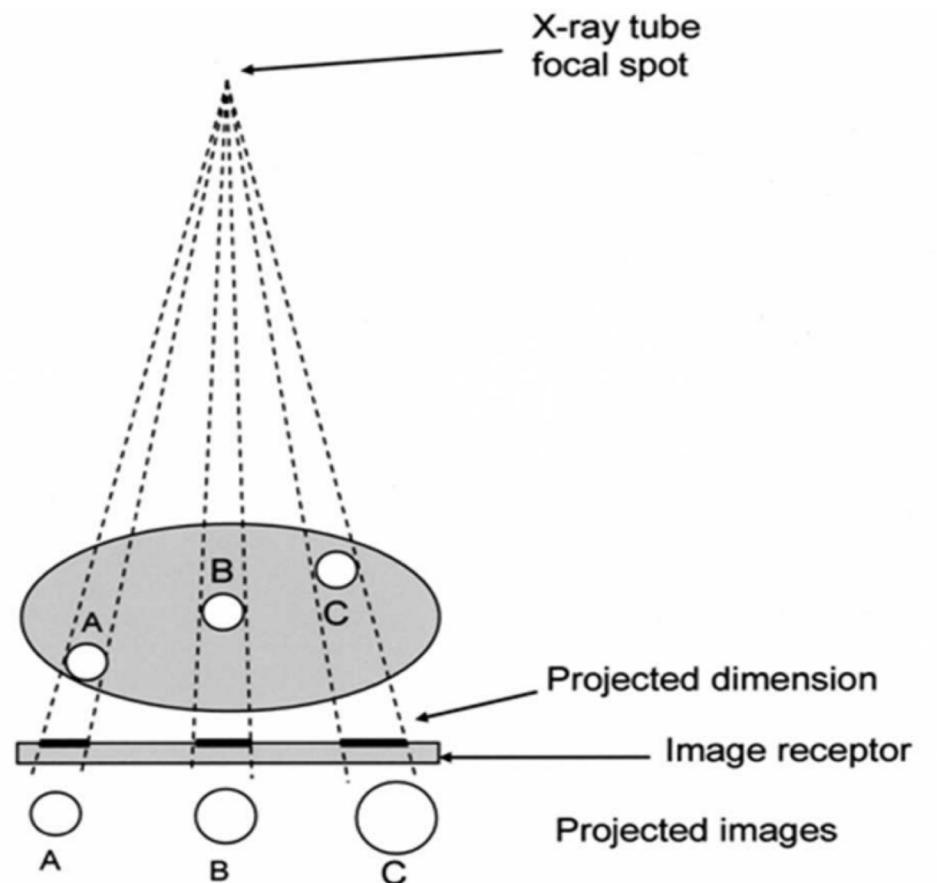
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# X-ray radiography



X-rays

**X-ray  
radiography**

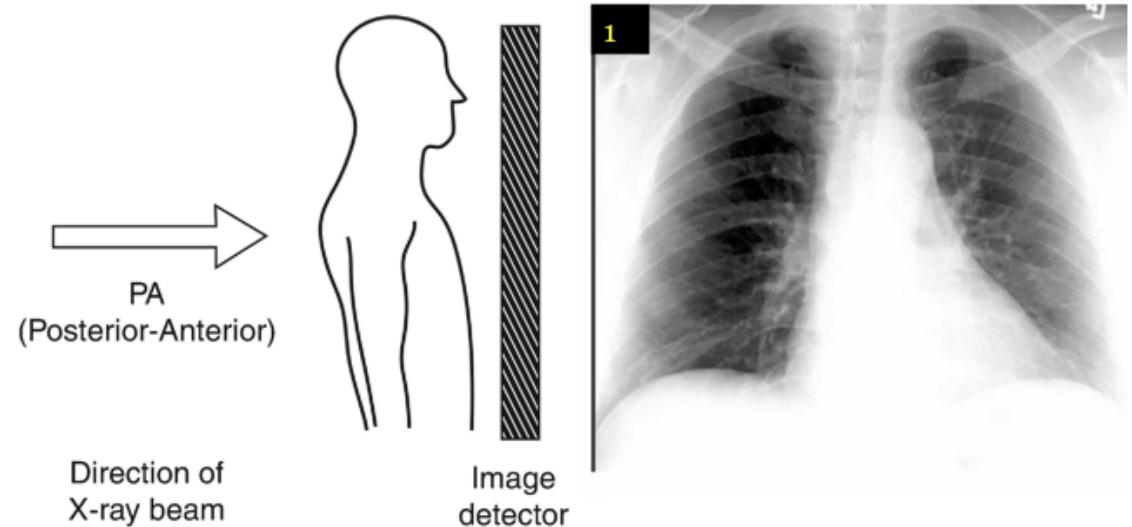
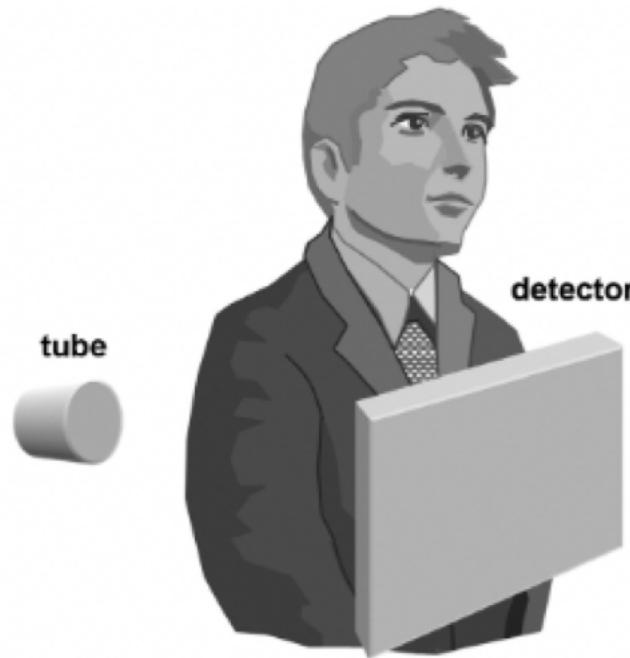
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# X-ray radiography



X-rays

**X-ray  
radiography**

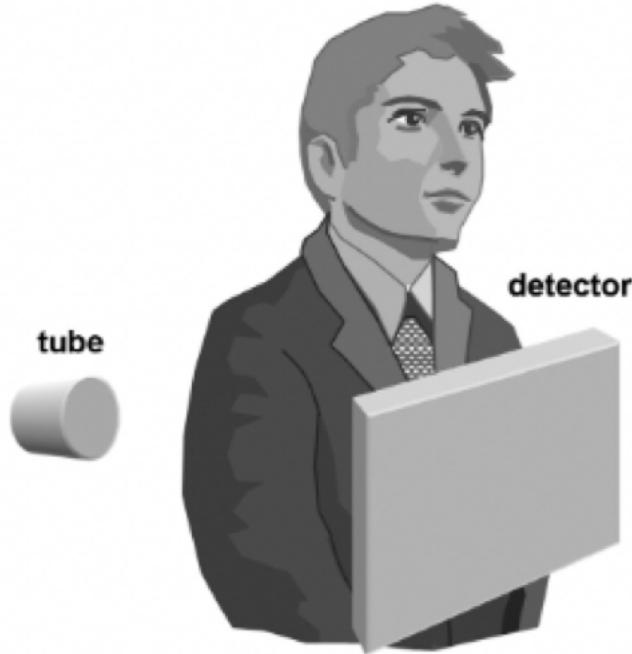
X-ray tomography

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# X-ray radiography



- Poor low-contrast resolution
- Bone & tissue superimposed
- Reduced visibility of the object of interest.

X-rays

X-ray  
radiography

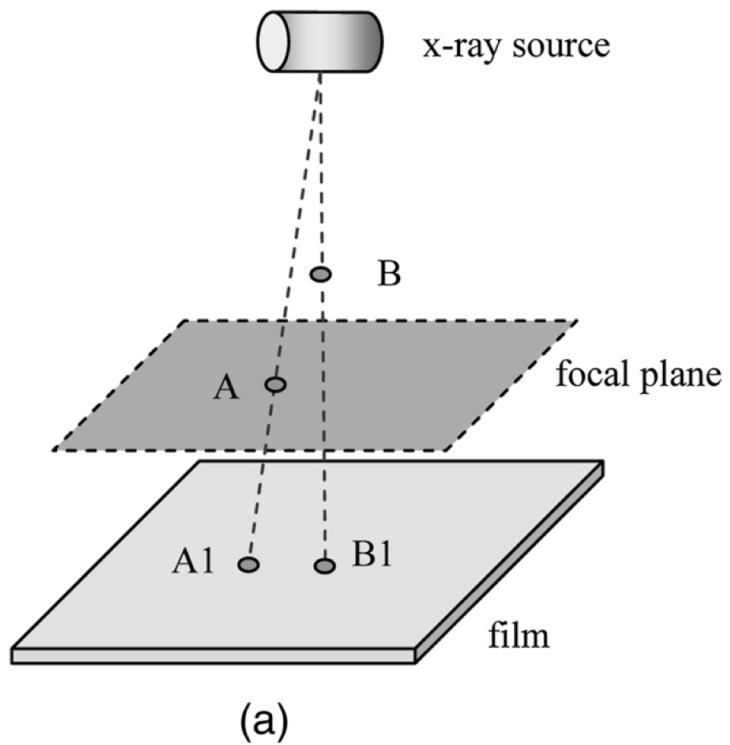
**X-ray  
tomography**

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# Conventional X-ray tomography



**Tomography:** imaging by sections or sectioning that uses any kind of penetrating wave. The word *tomography* is derived from Ancient Greek *tomos*, "slice, section" and γράφω *graphō*, "to write"

<https://en.wikipedia.org/wiki/Tomography>



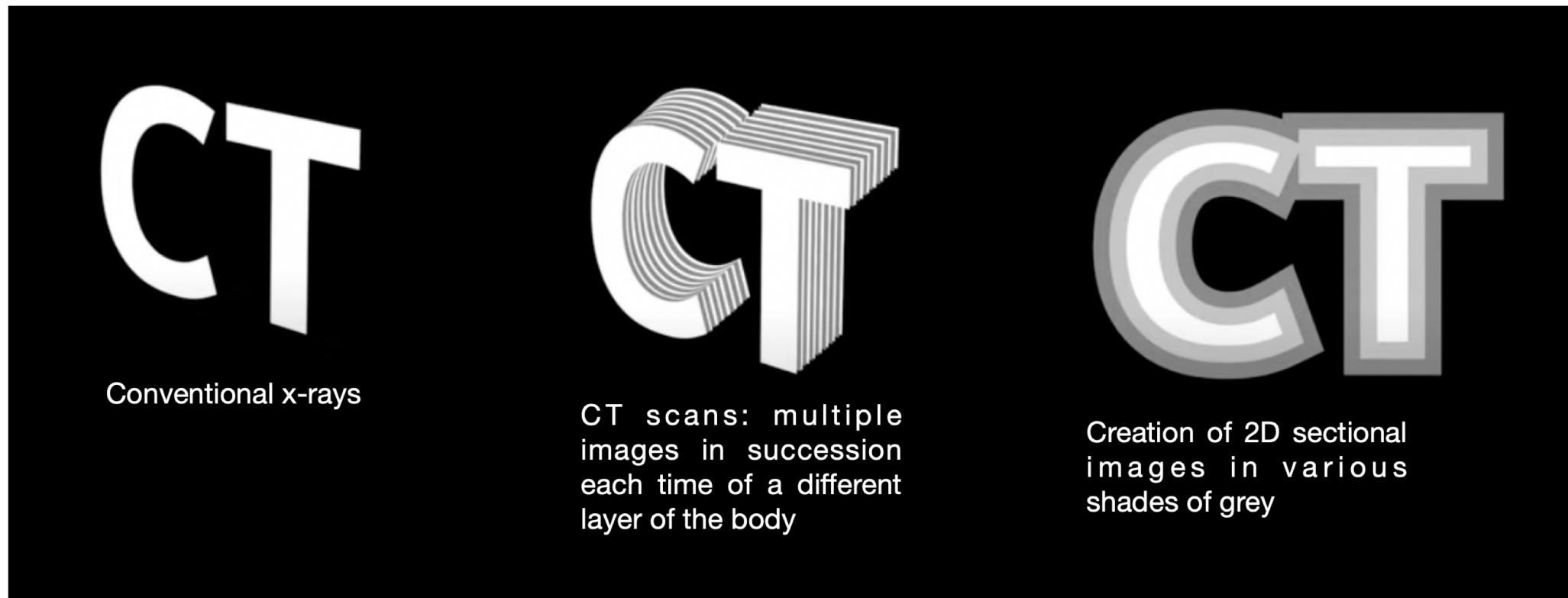
# Conventional X-ray tomography

- Planes close to the focal plane undergo little blurring.
- Conventional tomography blurs the overlying structure.
- Contrast between different structures inside the focal plane is not enhanced.
- the blurred overlying structures superimposed on the tomographic image significantly degrade the quality of the image.
- Large x-ray dose to the patient

**Limited clinical application**



# Idea



<https://www.youtube.com/watch?v=0OdNI3ISgLc>

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# Historical context

1940,  
Gabriel Frank

1961,  
William H. Oldendorf

1963,  
David E. Kuhl  
&  
Roy Q. Edwards

1963-1964,  
Allan Cormack

1979  
  
1968,  
**Godfrey Newbold Hounsfield**

**Backprojection design.**  
Today accomplished by a CT scanner using a computer.

Subject moved along a line as it rotated. Computer to sort out motions to carry out the back projections and display the results on a computer screen.

Transverse tomography further developed and evolved into today's emission computed tomography.

Solution of line integrals problem. Reported the findings from investigations of perhaps the first CT scanner actually built.

**Patent submission.**  
X-ray measurements of a body taken from different directions allow the reconstruction of its internal structure.

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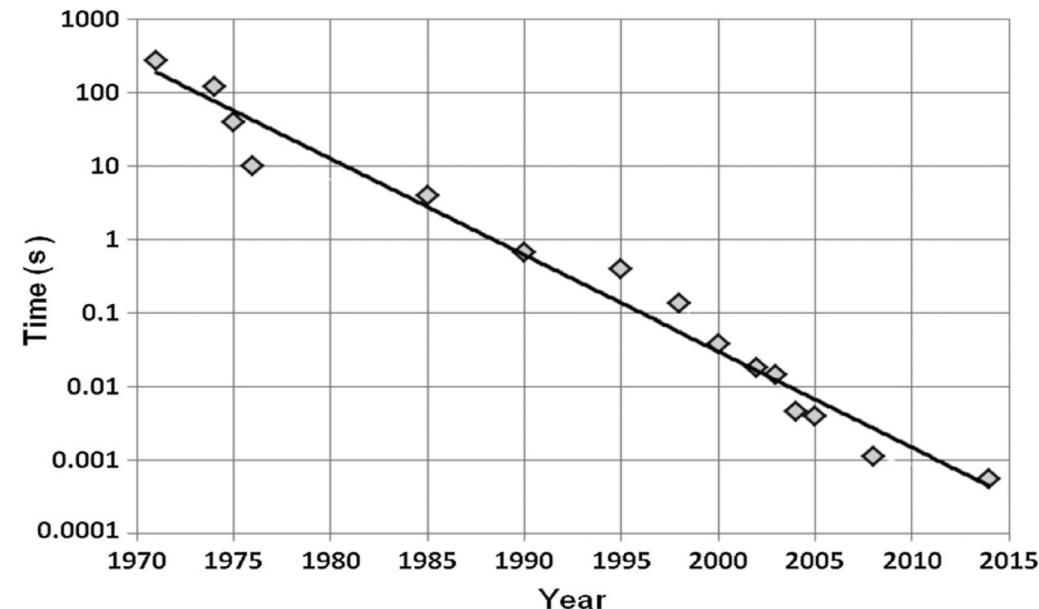
Ultrasound

# Historical context



1971: 1st CT scan at London's Atkinson-Morley Hospital

4.5 min



$< 10^{-2}$  s



X-rays

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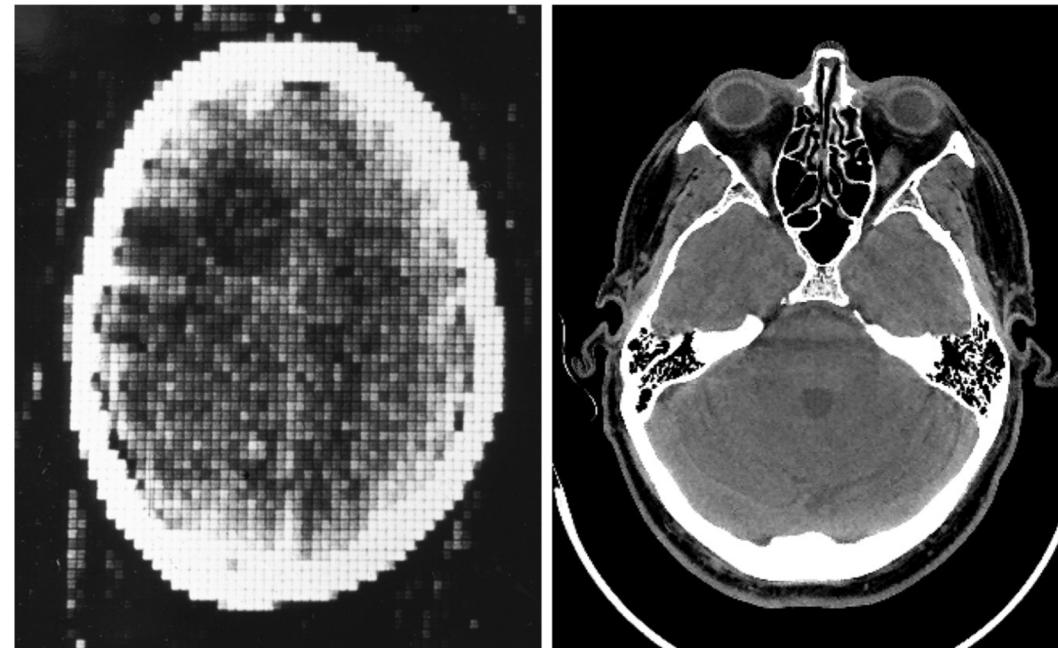
X-ray tomography

**Computed  
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# Historical context



First CT  
scanners

GE LightSpeed  
VCT 2005

X-rays

X-ray  
radiography

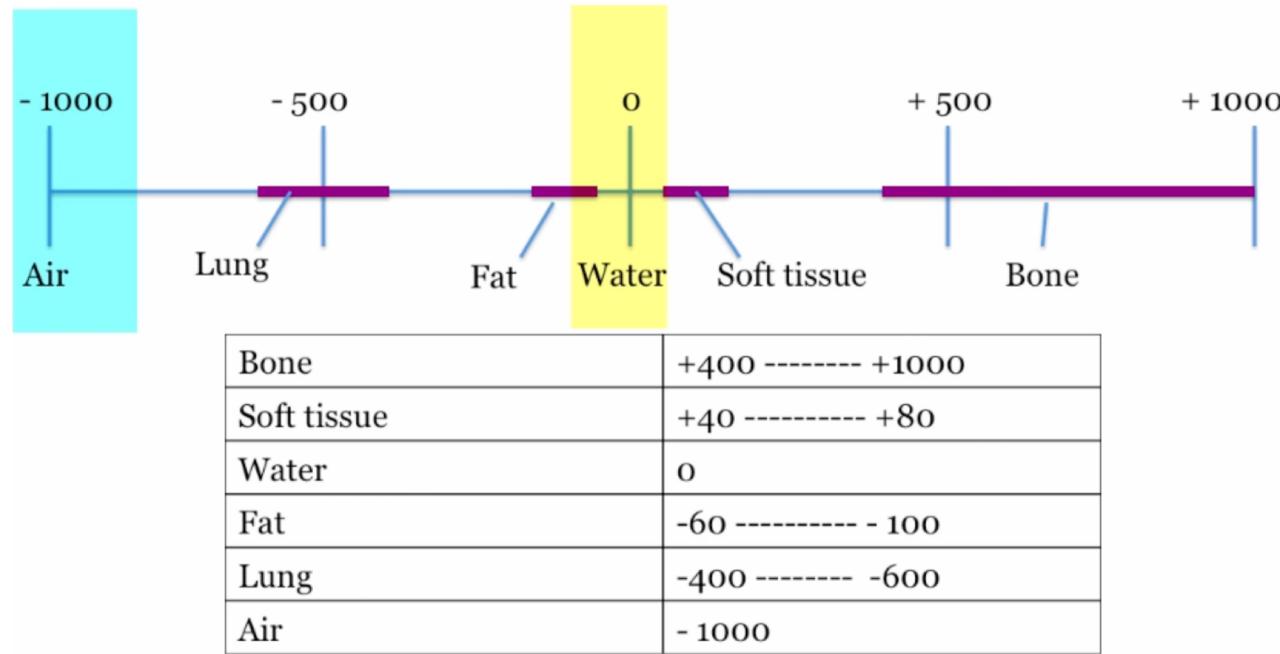
X-ray tomography

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# Hounsfield units



Hounsfield unit = a measure of radiodensity



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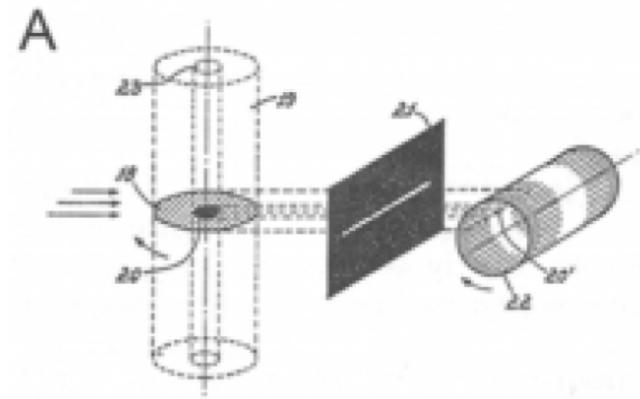
Computed  
tomography

Magnetic  
Resonance

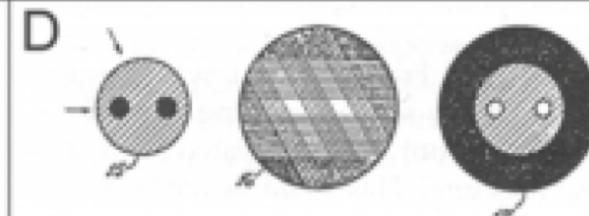
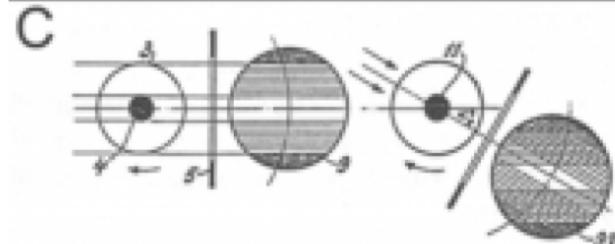
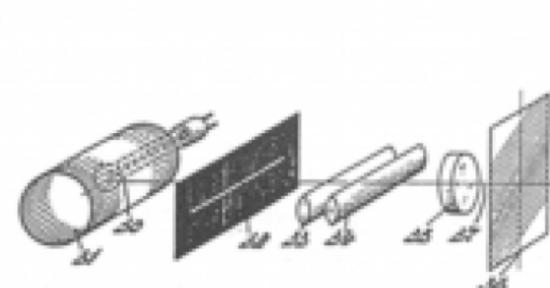
Ultrasound

# Back projection design

Linear exposures  
record



Film image creation



X-rays

X-ray  
radiography

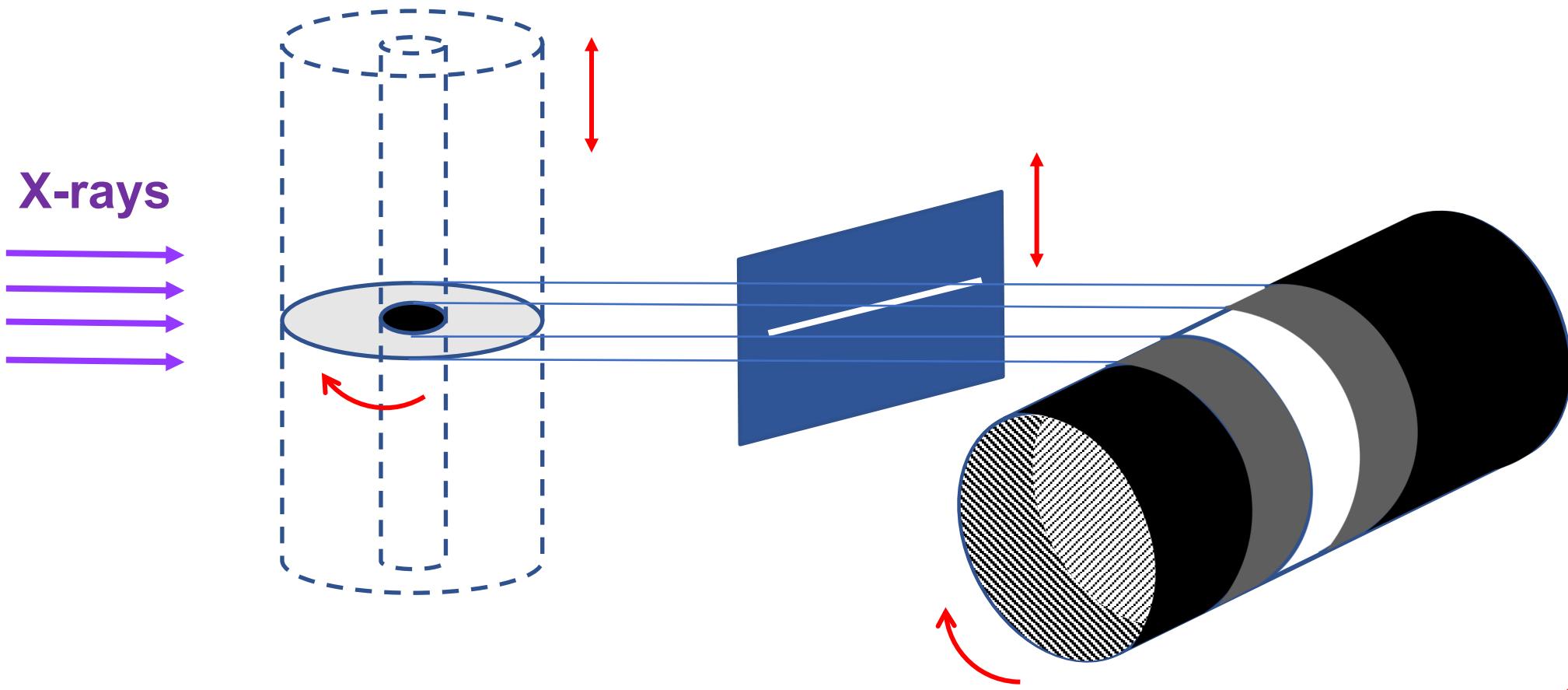
X-ray tomography

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# Back projection design



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X-ray  
radiography

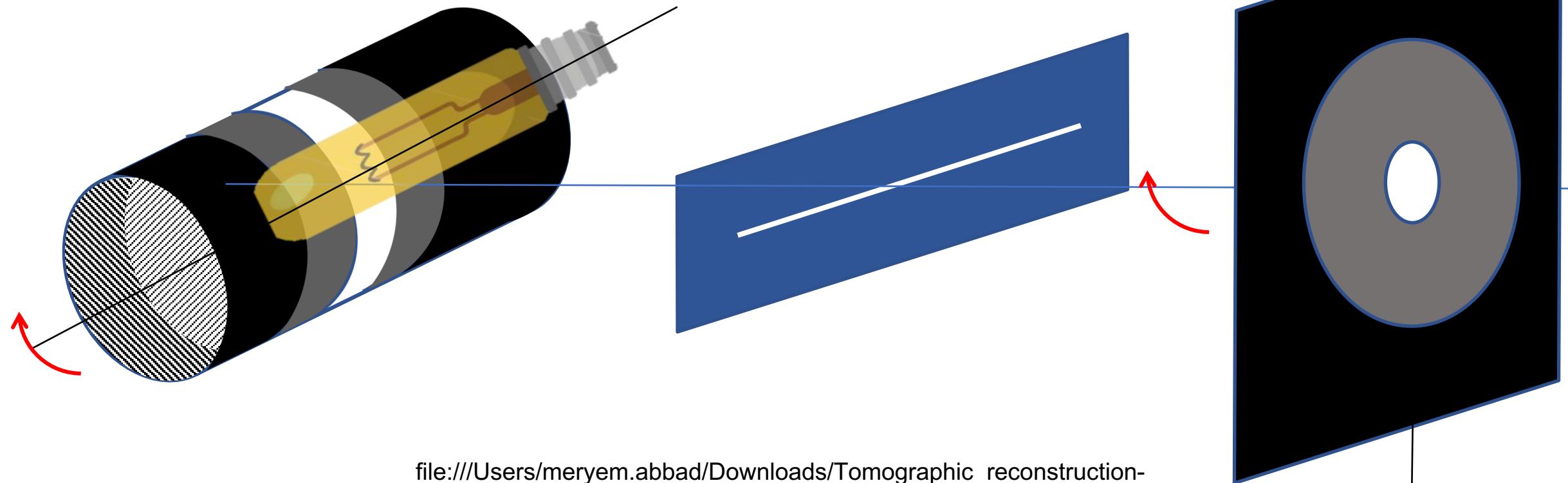
X-ray tomography

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# Back projection design



[file:///Users/meryem.abbad/Downloads/Tomographic\\_reconstruction-  
\\_Projection,\\_Back\\_projection\\_and\\_Filtered\\_back\\_projection.webm](file:///Users/meryem.abbad/Downloads/Tomographic_reconstruction-Projection,_Back_projection_and_Filtered_back_projection.webm)

X-rays

X-ray  
radiography

X-ray tomography

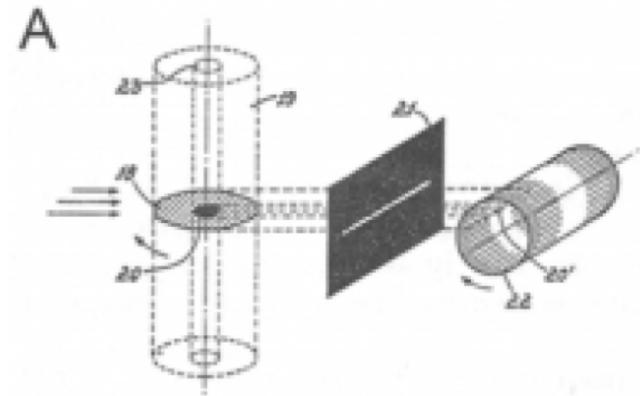
Computed  
tomography

Magnetic  
Resonance

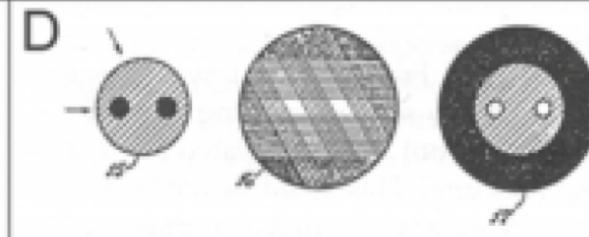
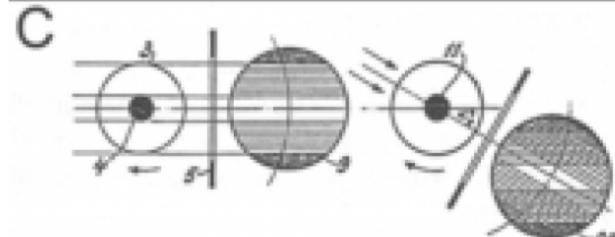
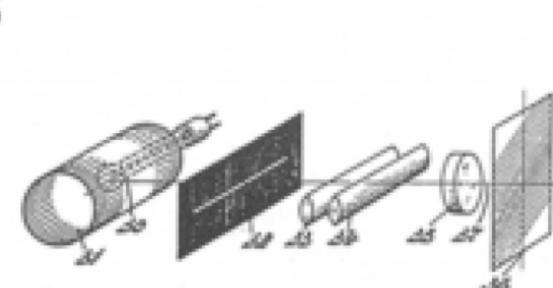
Ultrasound

# Back projection design

Linear exposures  
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Film image creation



X-rays

X-ray  
radiography

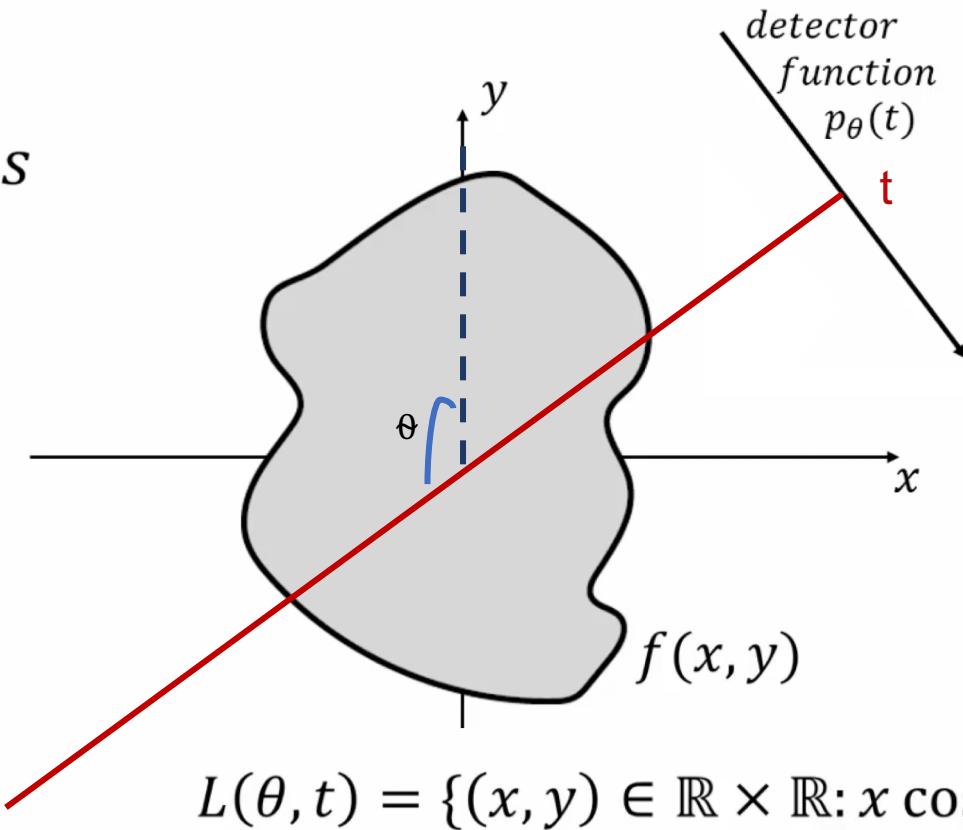
X-ray tomography

**Computed  
tomography**Magnetic  
Resonance

Ultrasound

# Radon transform

$$p_\theta(t) = \int_{L(\theta,t)} f(x,y) ds$$



X-rays

X-ray  
radiography

X-ray tomography

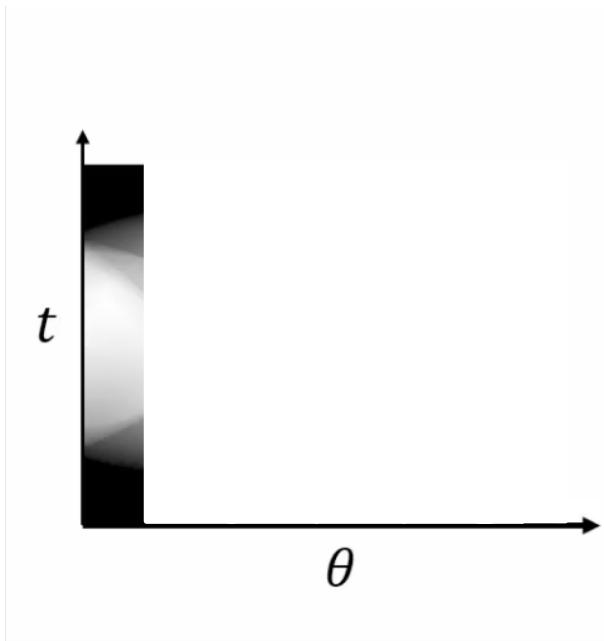
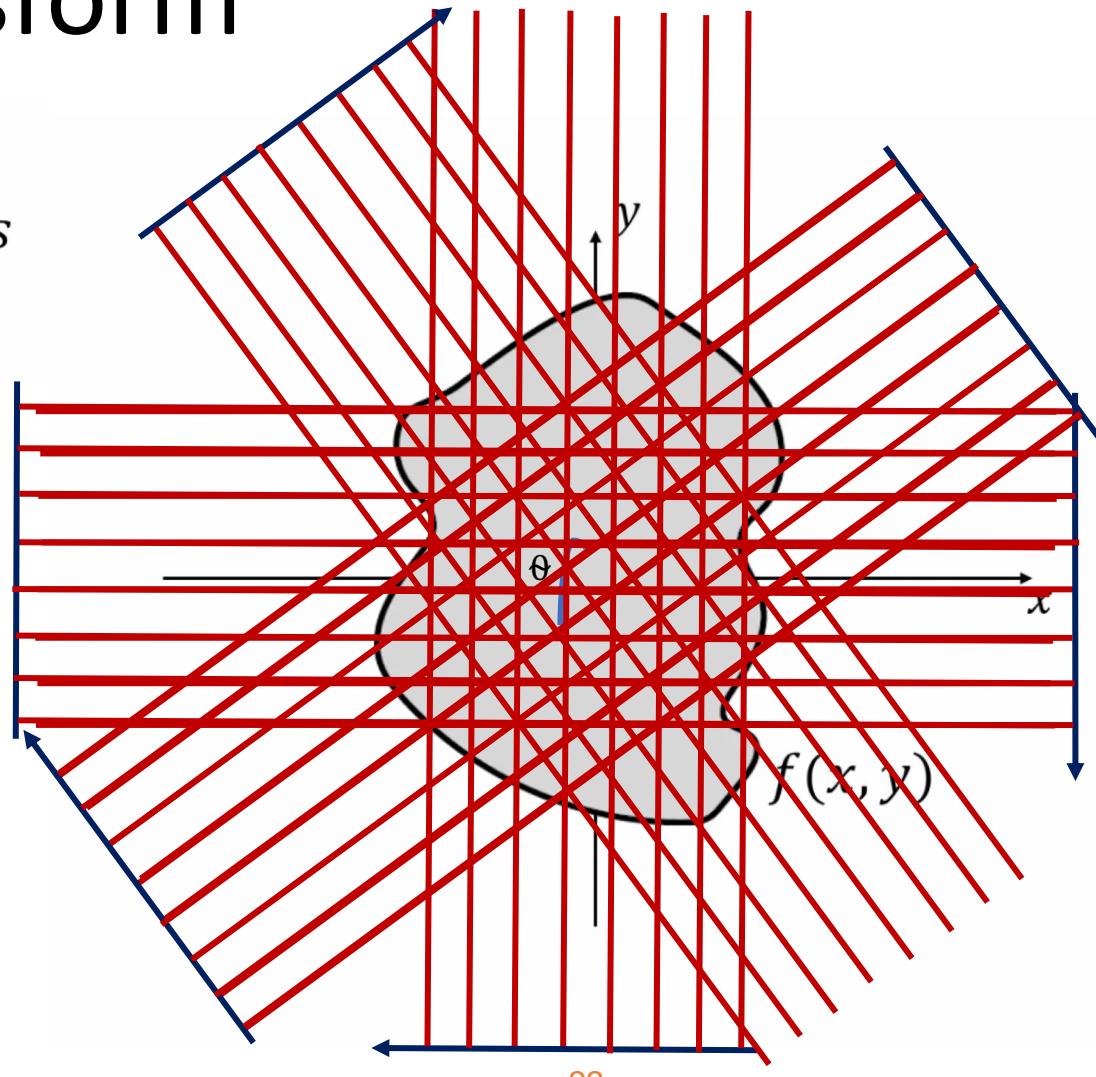
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tomography

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Ultrasound

# Radon transform

$$\mathcal{R}f(\theta, t) = \int_{L(\theta,t)} f(x, y) ds$$



[https://en.wikipedia.org/wiki/Radon\\_transform#/media/File:Radon\\_transform\\_sinogram.gif](https://en.wikipedia.org/wiki/Radon_transform#/media/File:Radon_transform_sinogram.gif)

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radiography

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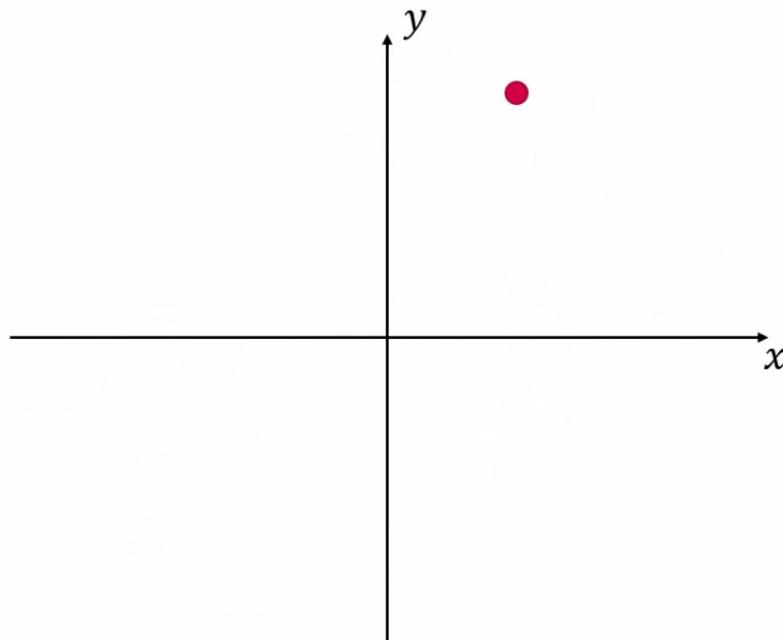
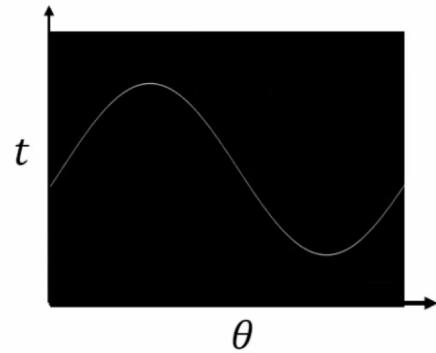
Magnetic  
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# Radon transform

$$\mathcal{R}f(\theta, t) = \int_{L(\theta, t)} f(x, y) ds$$

Sinogram



[https://www.youtube.com/watch?v=MA2y\\_2YySq0](https://www.youtube.com/watch?v=MA2y_2YySq0)

X-rays

X-ray  
radiography

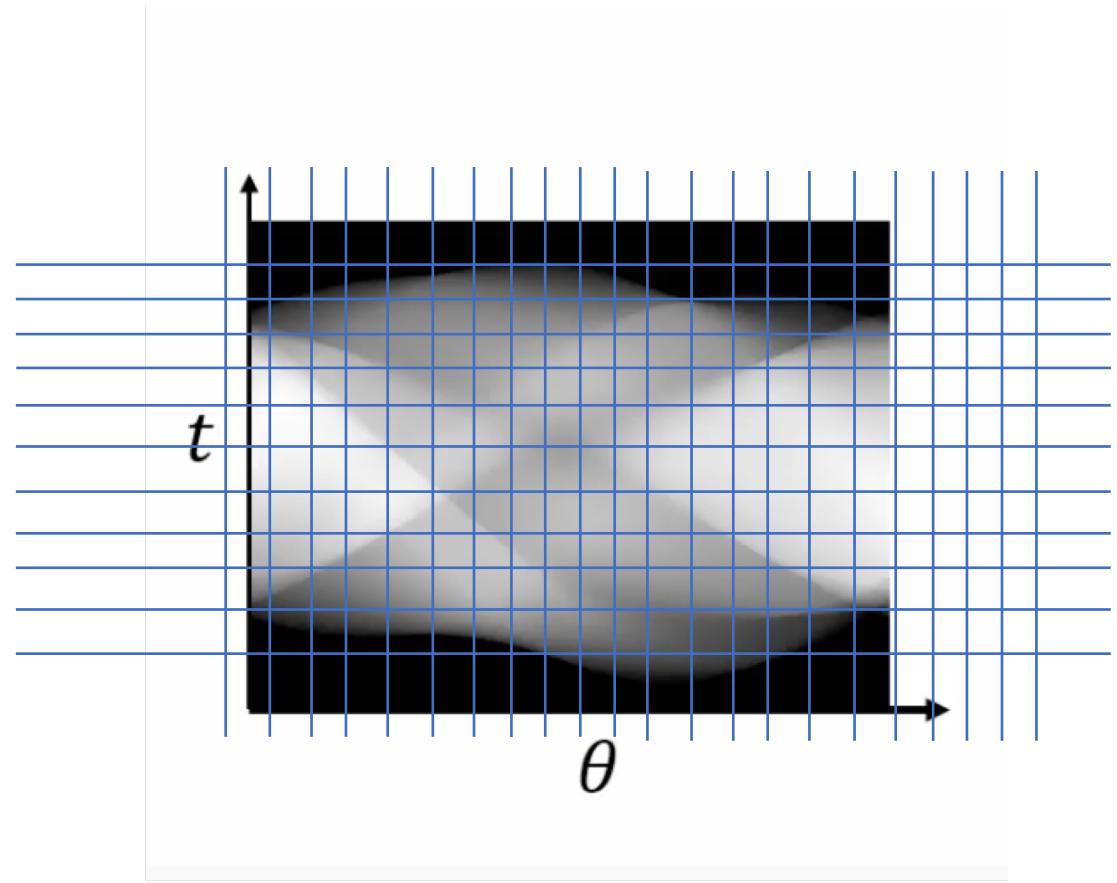
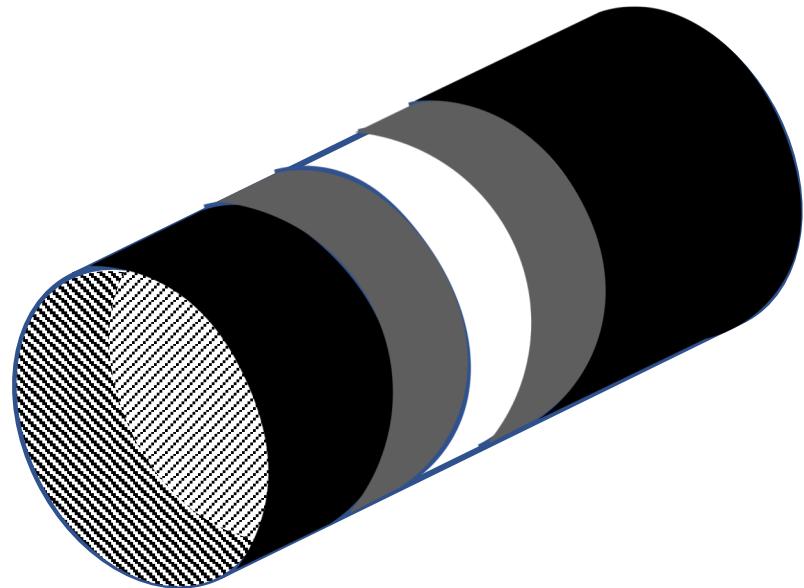
X-ray tomography

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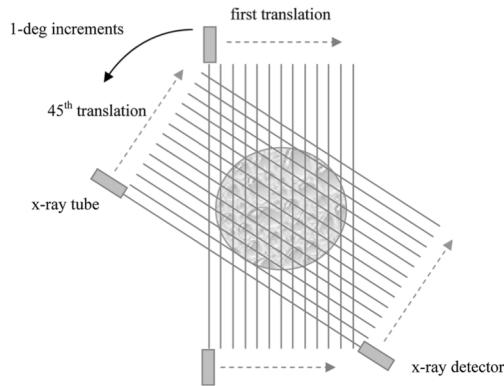
# Inverse radon transform vs iterative back projection



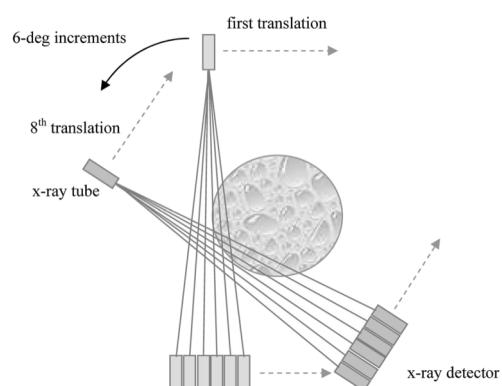


# 4 generations

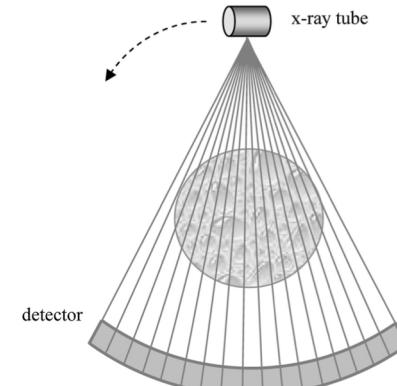
1971, first-generation CT



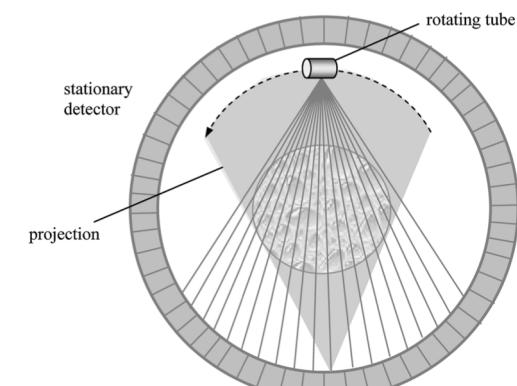
Second generation



Third generation

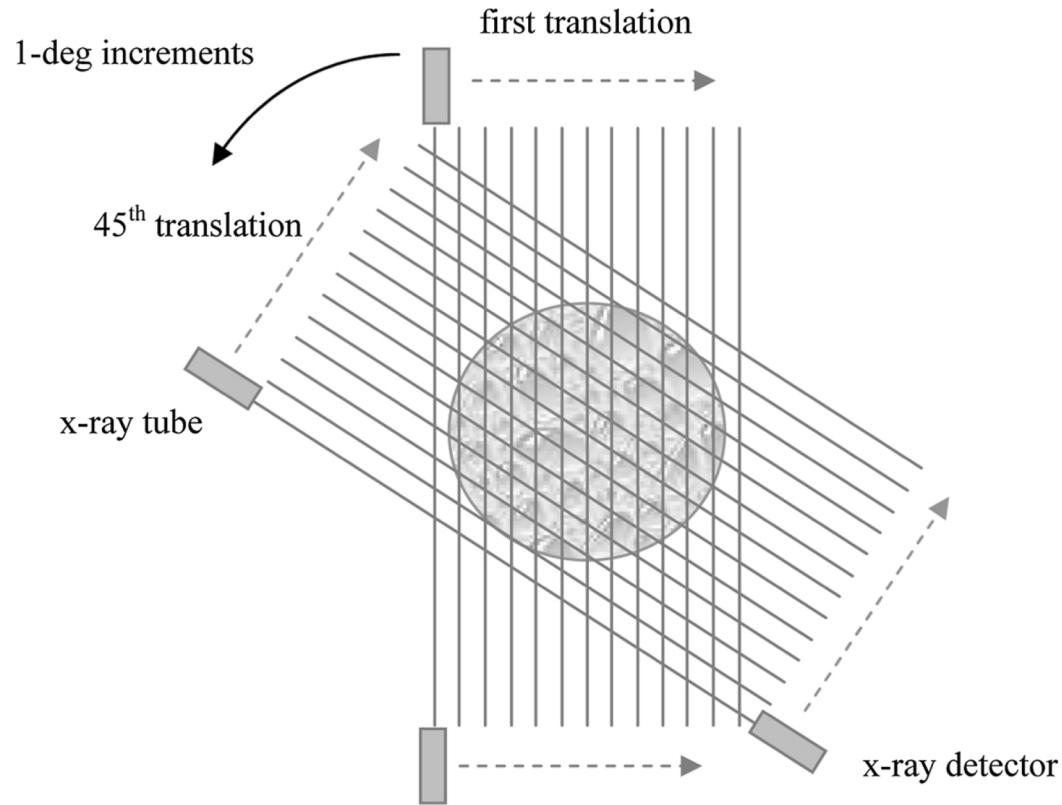


Fourth generation



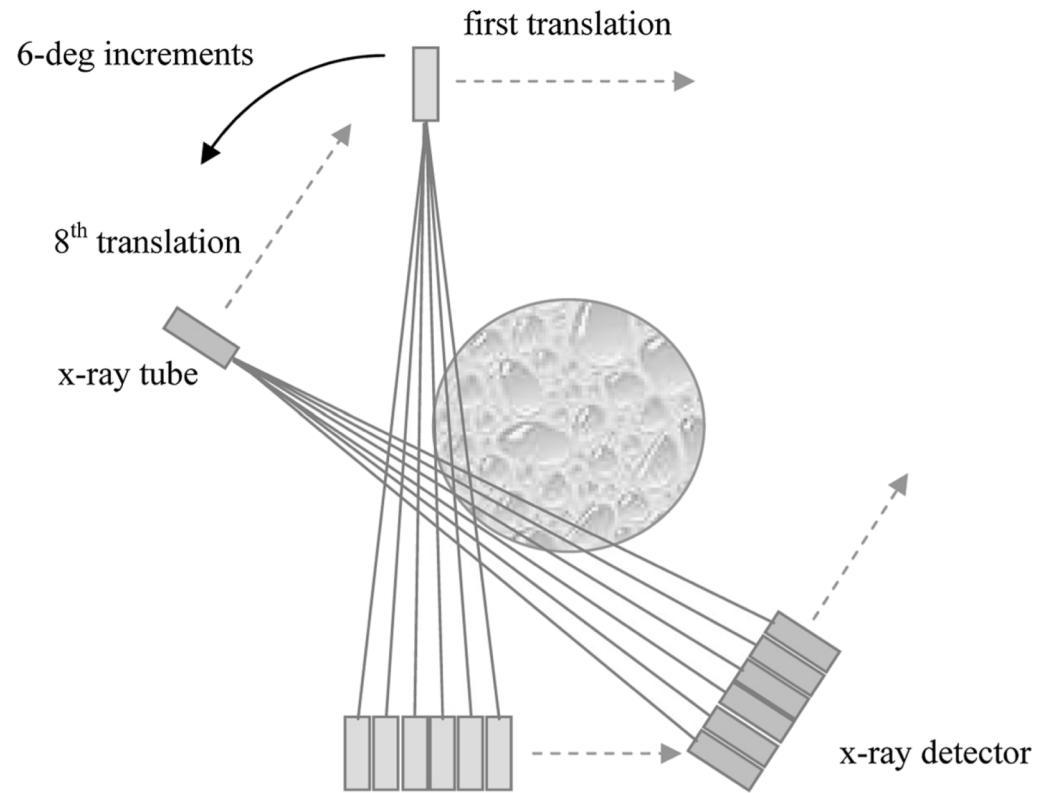


# 1<sup>st</sup> generation



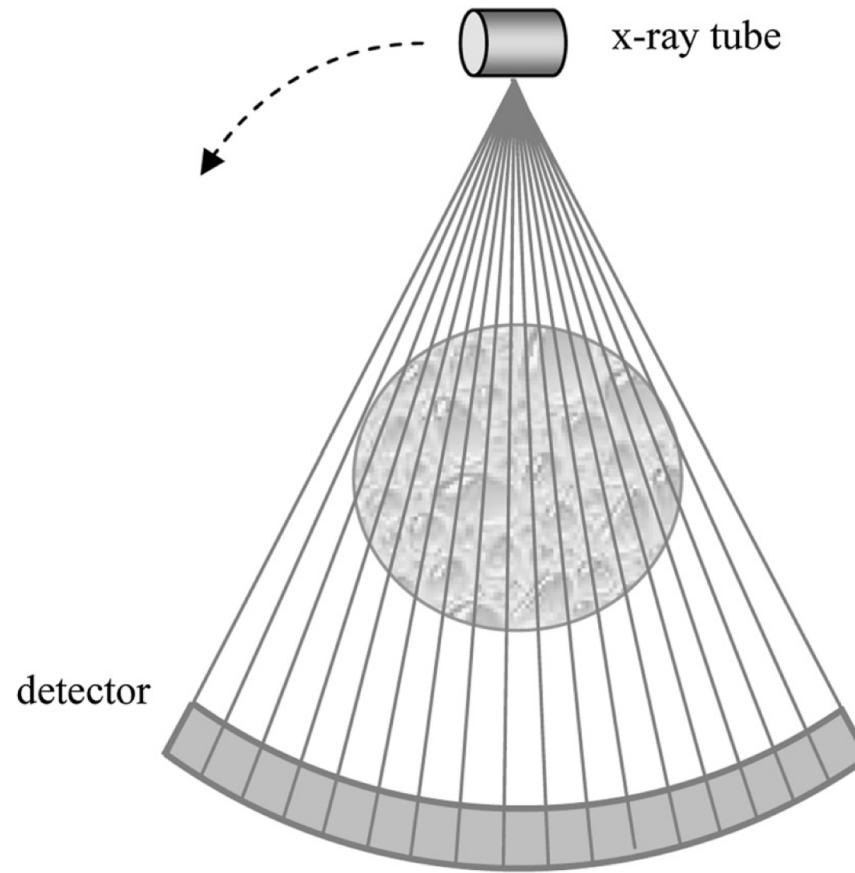


## 2<sup>nd</sup> generation



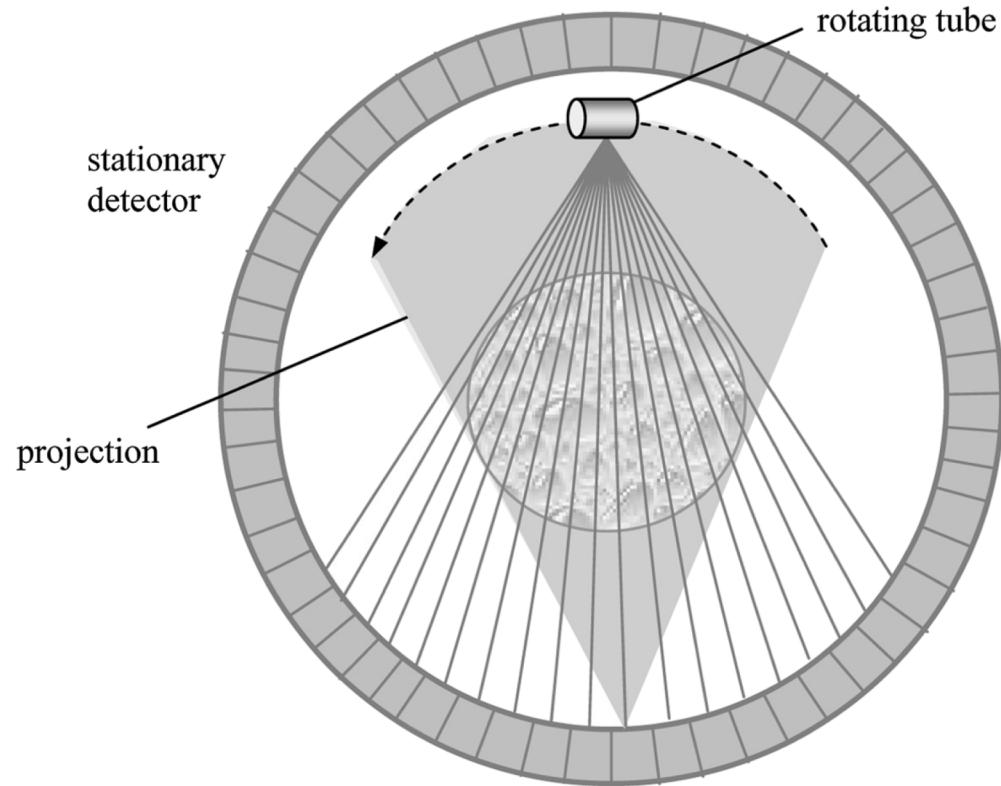


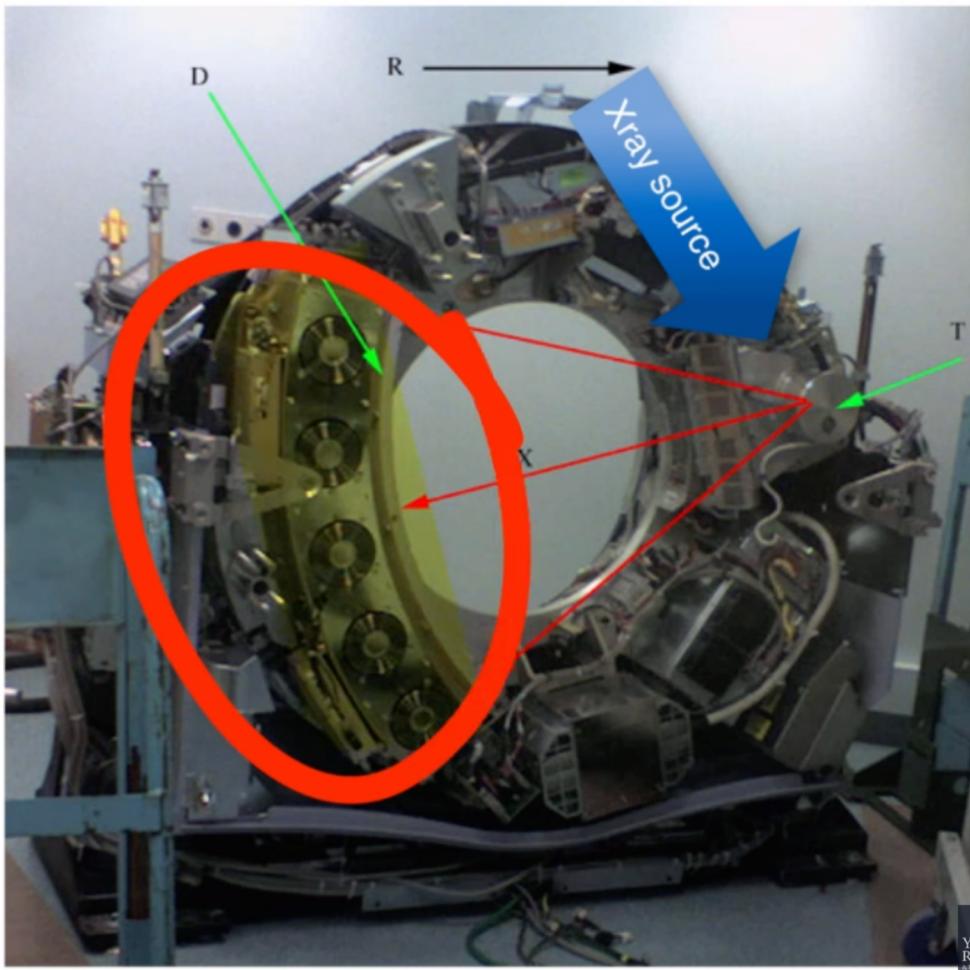
# 3<sup>rd</sup> generation





# 4<sup>th</sup> generation





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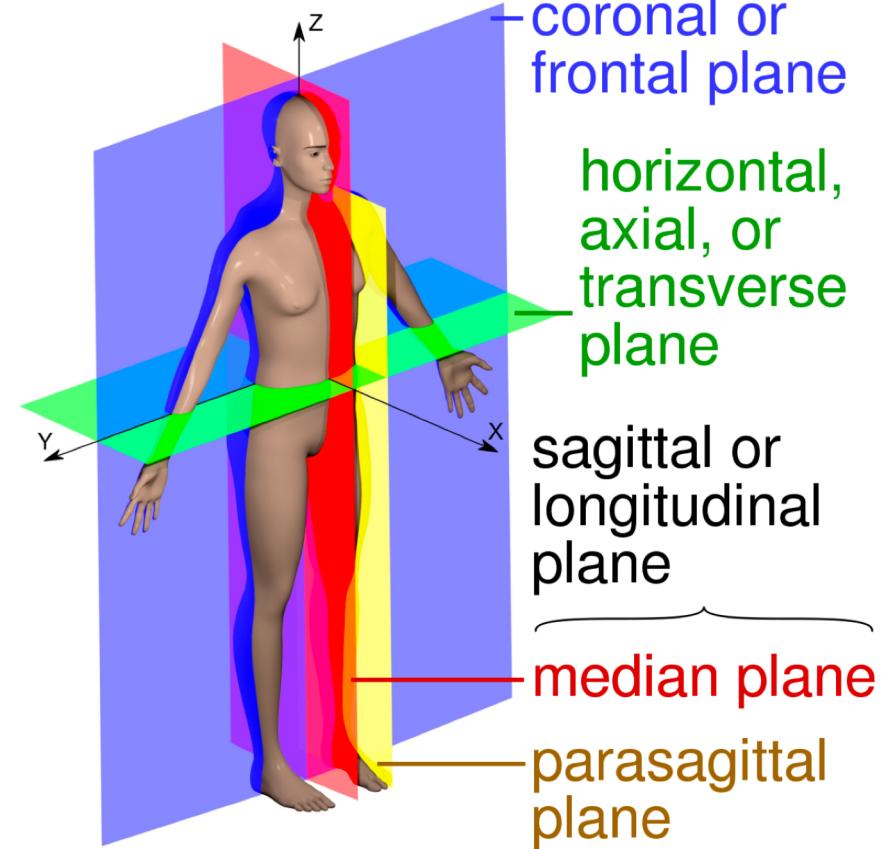
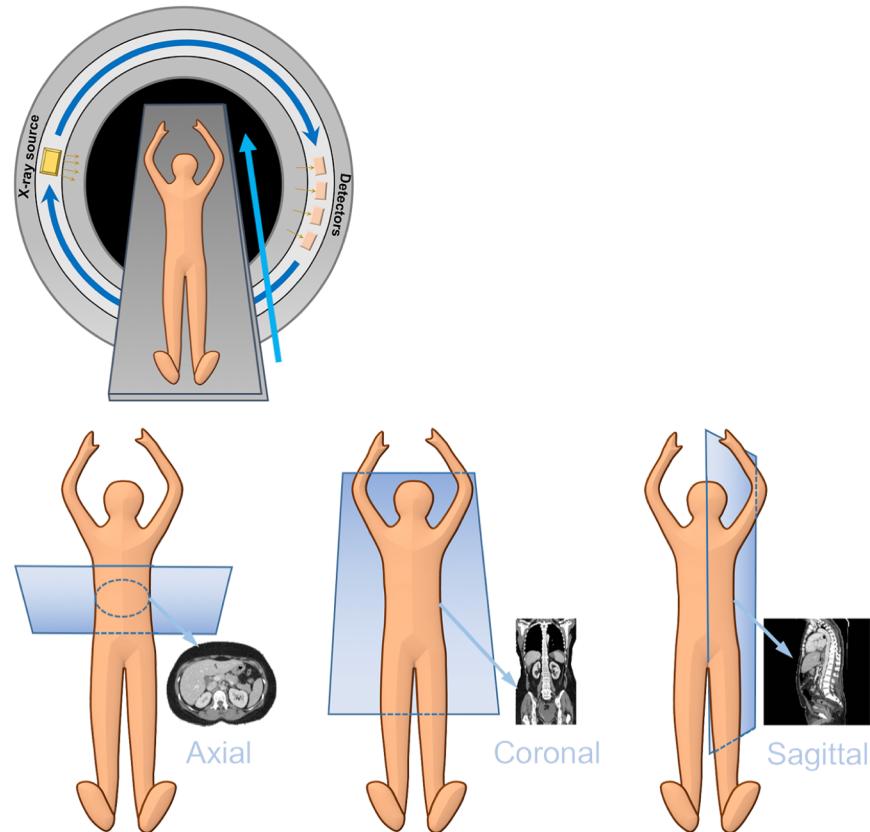
X-ray tomography

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# Anatomical planes



X-rays

X-ray  
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X-ray tomography

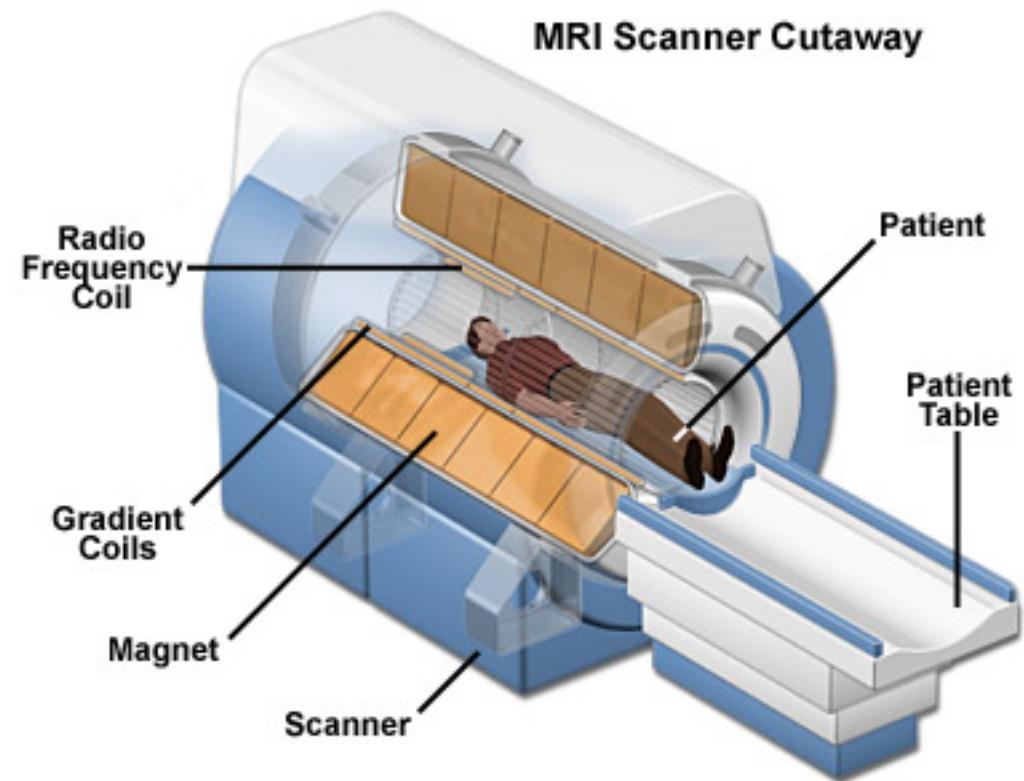
Computed  
tomography

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Ultrasound

# Principle

- Our body: Hydrogen atoms. 1 proton and 1 electron. The proton rotates around its axis.
- Patient placed in strong uniform magnetic field aligning positively charged hydrogen ions (hydrions) or protons. (1.5 T, 3T)
- Impose a temporary radiofrequency pulse to scatter hydrogen protons: creation of electric charge.
- By applying magnetic pulses, the tissue properly dependent response of the previously aligned protons can be measured by a detector.
- Time from excitation to detection (TE)
- Time before pulses (TR)



<https://nationalmaglab.org/education/magnet-academy/learn-the-basics/stories/mri-a-guided-tour>

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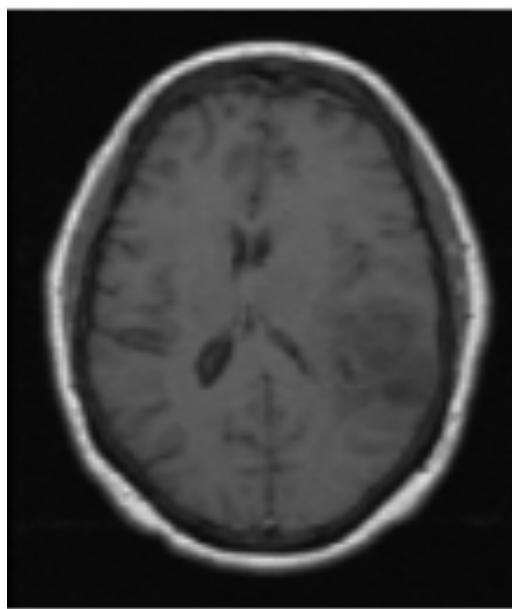
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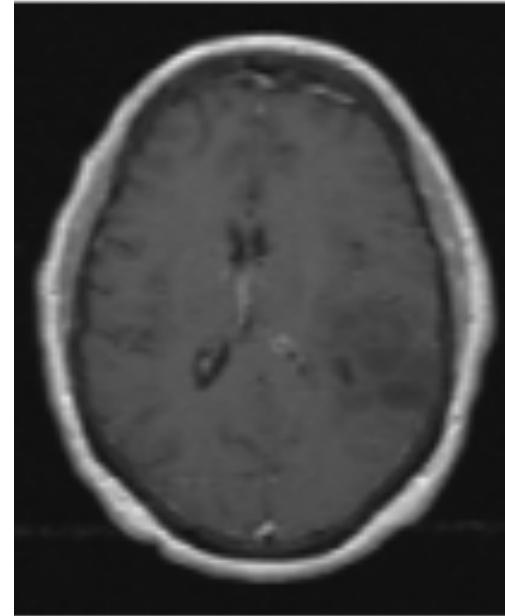
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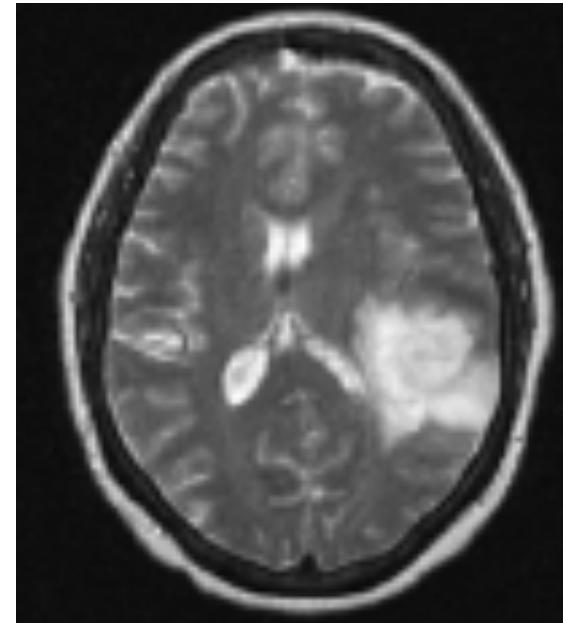
# Different sequences



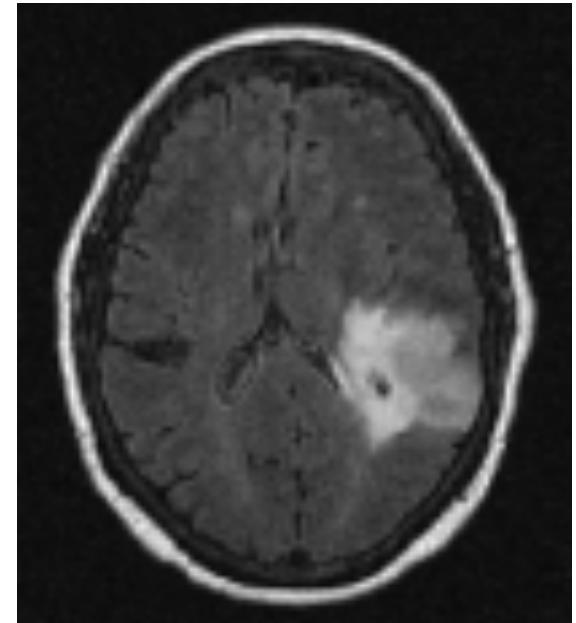
T1



T1 Gd



T2



FLAIR

X-rays

X-ray  
radiography

X-ray tomography

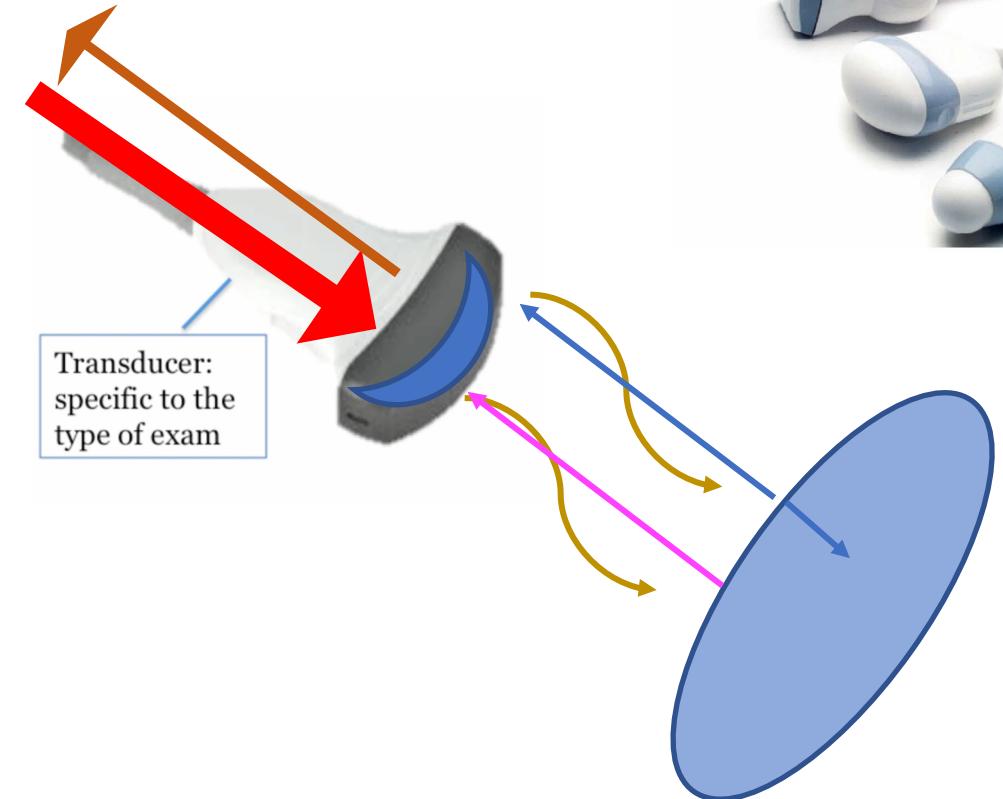
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**Ultrasound**

# Principle

- Sound waves.
- Different Transducers (piezo electric crystals. Change shape with electrical impulse: sound waves (2-20 MHz).
- Waves travel differently in the body. [transmitted, reflected, in between]





<https://en.wikipedia.org/wiki/Ultrasound>