Lecture 16: Medical Imaging

(Quiz)

0. Review
1. Intro
2. Radiography
3. CT
4. MRI
5. Ultrasound

This week:

Lab Practical (see website)

Exam #2 Thu (Mar 5)
→ Course website has PreLab, QZ, HW solns, 2019 exam + solns

Lab 6 Report due Fri (Mar 6)

Next week:

Student presentations (Mar 10 + 12)

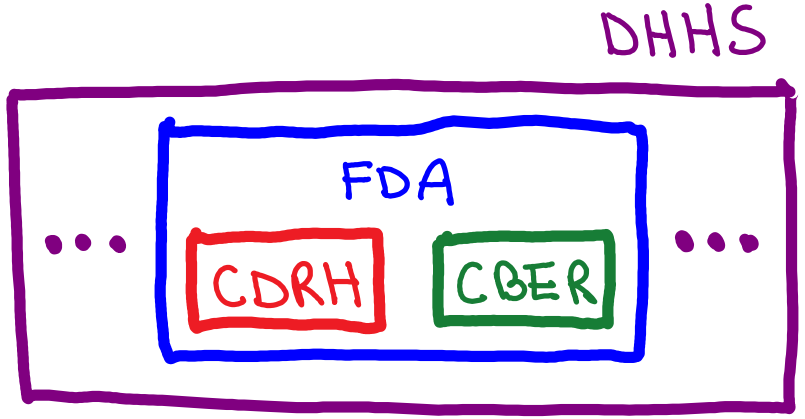
Ellis Tour (Mar 10)
Group 1 (12:45 - 2:30)
2 (2:45 - 4:30)

Meet in ISEC 150

Ethics paper due Fri (Mar 13)

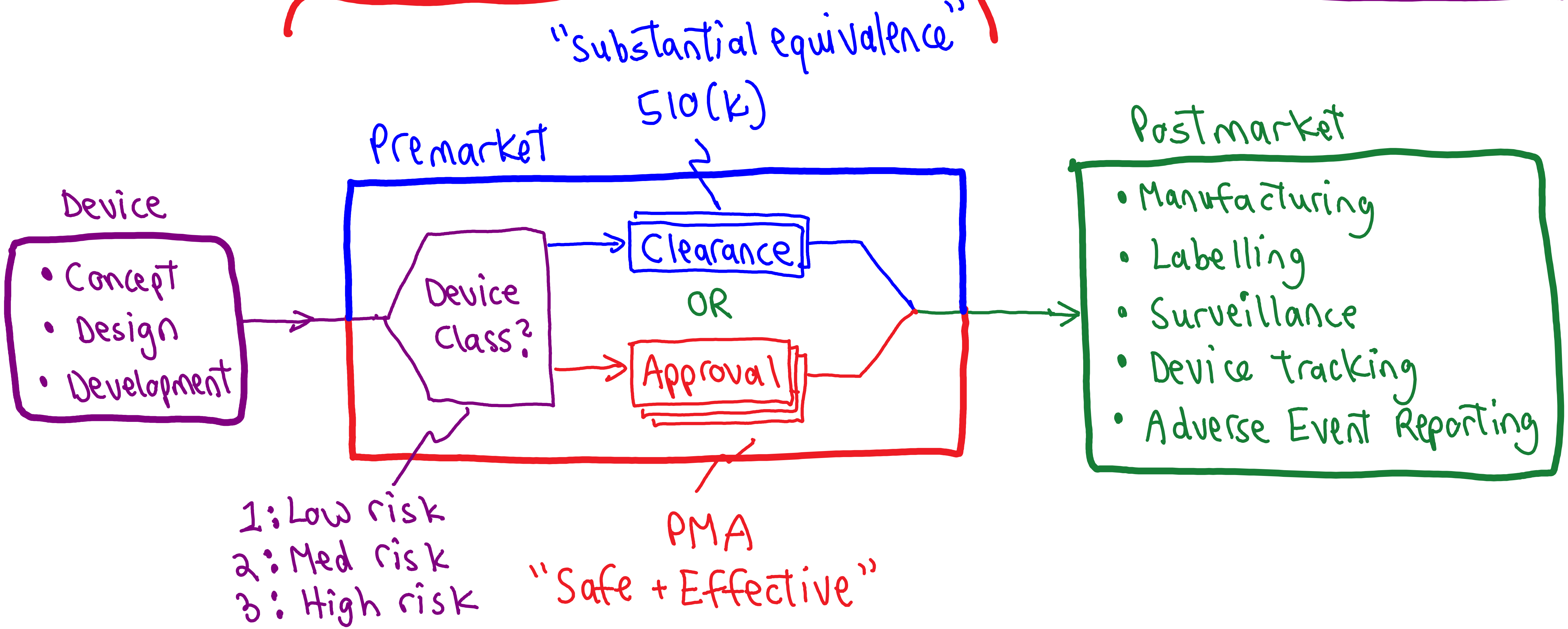
- See FDA website for database
- Email topic to Buma

0. Review



1976: Medical Device Amendments (MDA)

→ Premarket requirements



1. Intro

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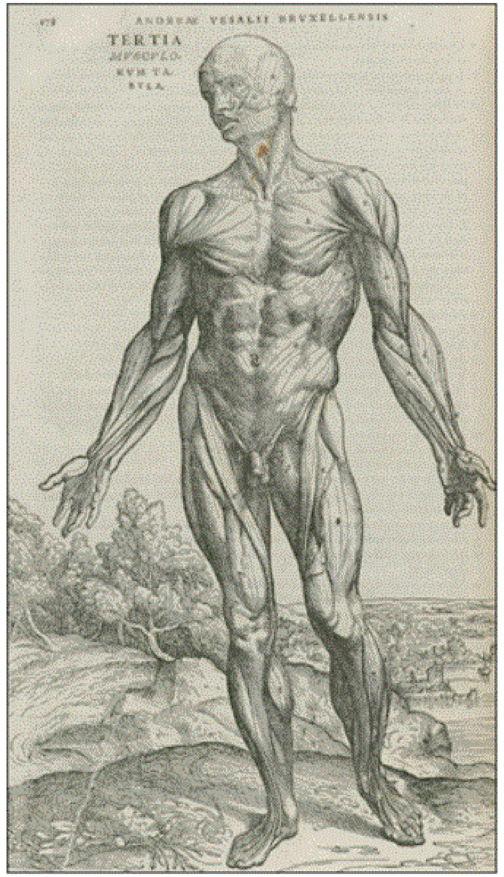
Medical Illustration



(1895)

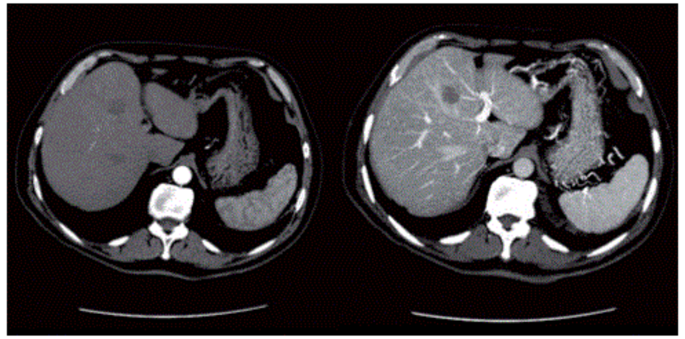
1st X-ray image

www.nlm.nih.gov/exhibition/dreamanatomy/da_gallery.html

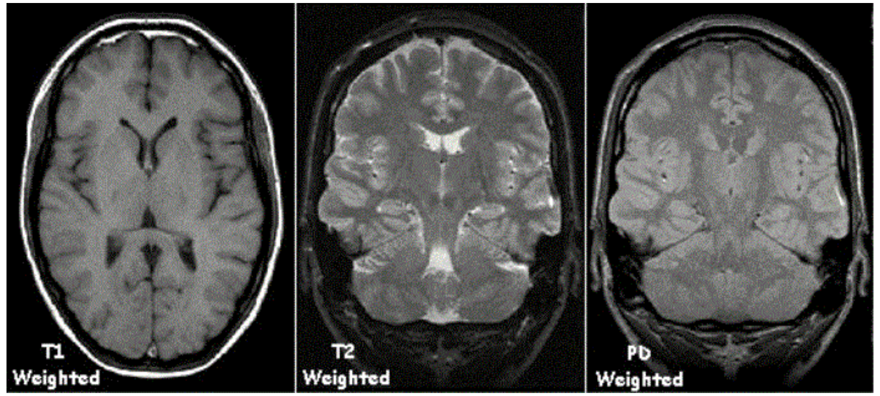
VS.

Today...

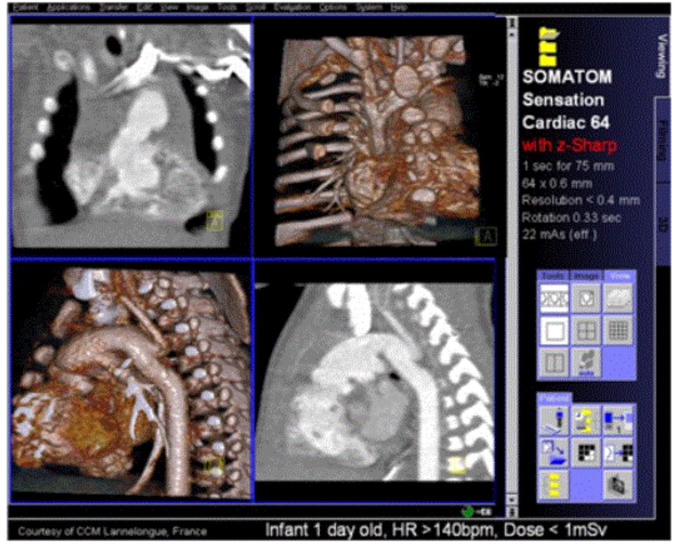
CT (GE)



MRI (wikipedia)



Multi-slice CT



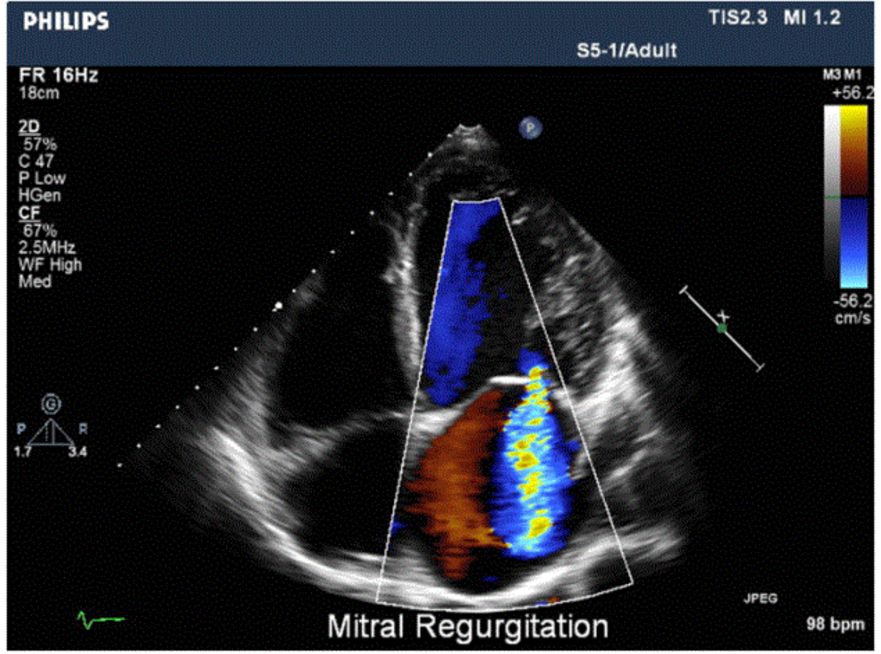
SOMATOM Sensation Cardiac 64
with z-Sharp
1 sec for 75 mm
64 x 0.6 mm
Resolution < 0.4 mm
Rotation 0.33 sec
22 mAs (eff.)

Courtesy of CCM Lannelongue, France

Infant 1 day old, HR >140bpm, Dose < 1mSv

(siemens)

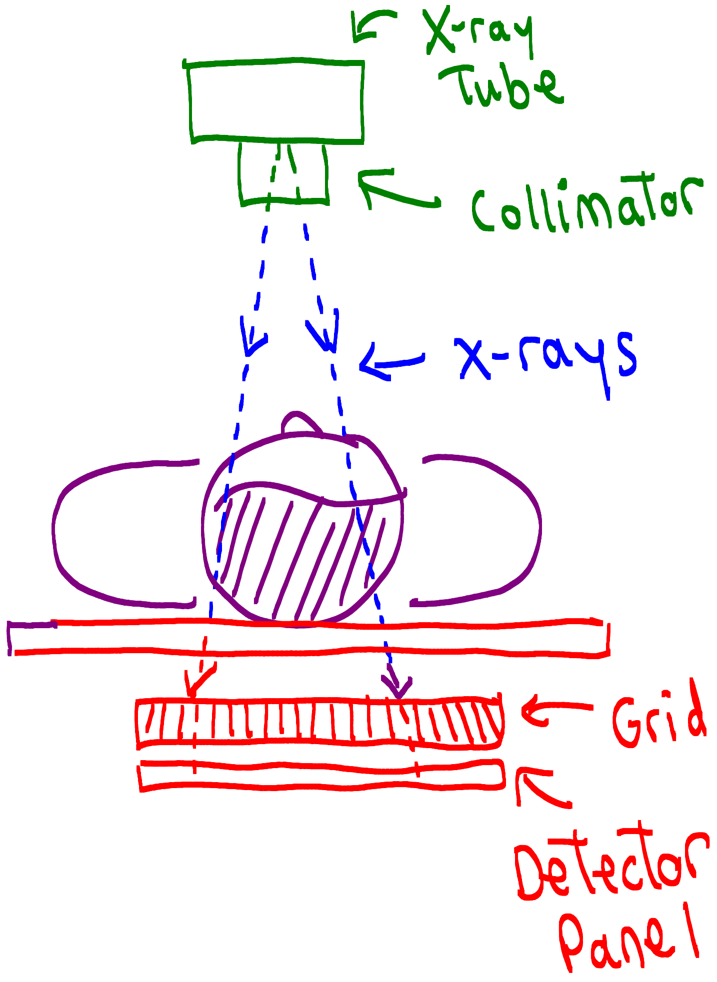
Ultrasound (Philips)

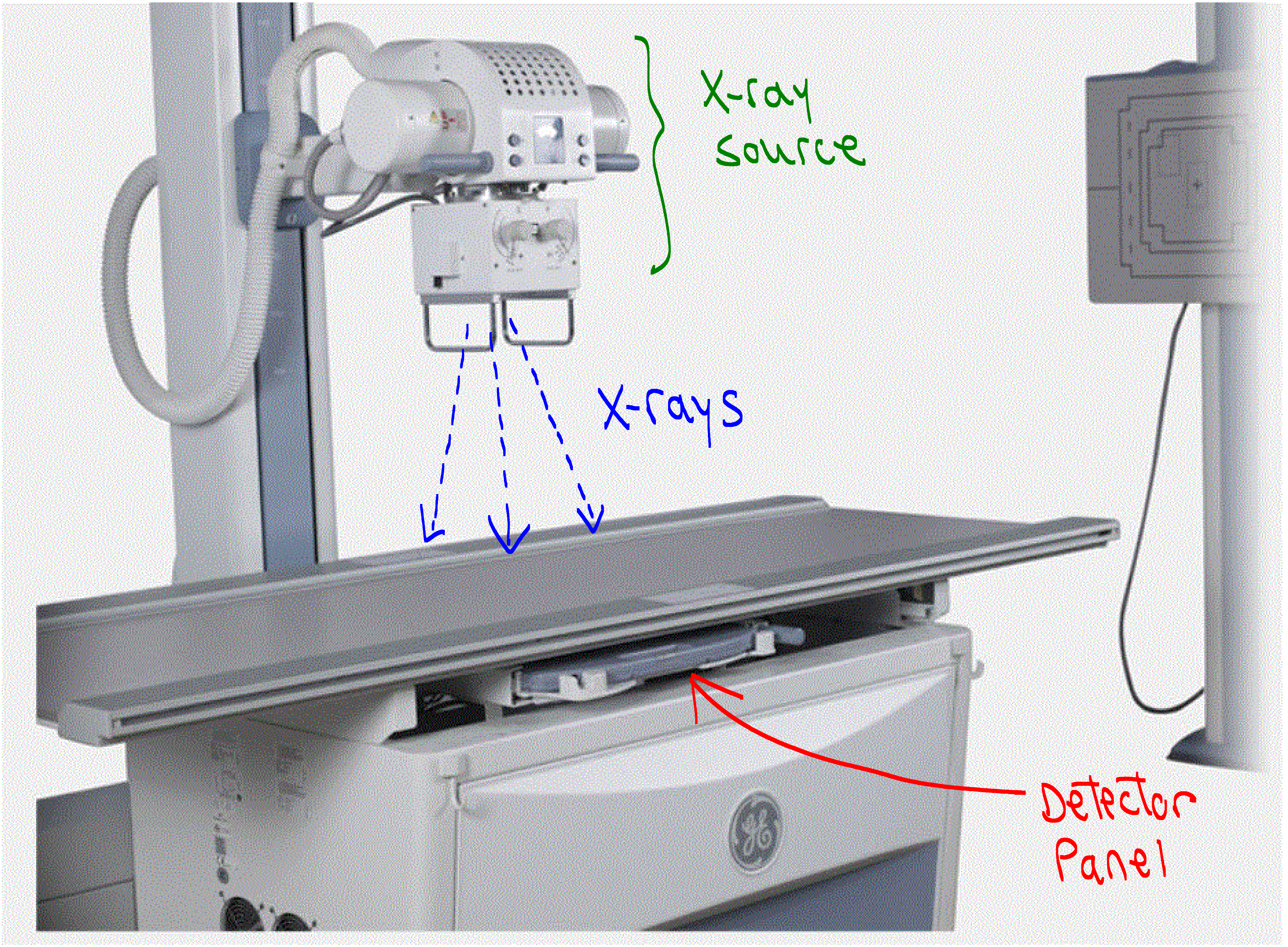


Mitral Regurgitation

2. Radiography

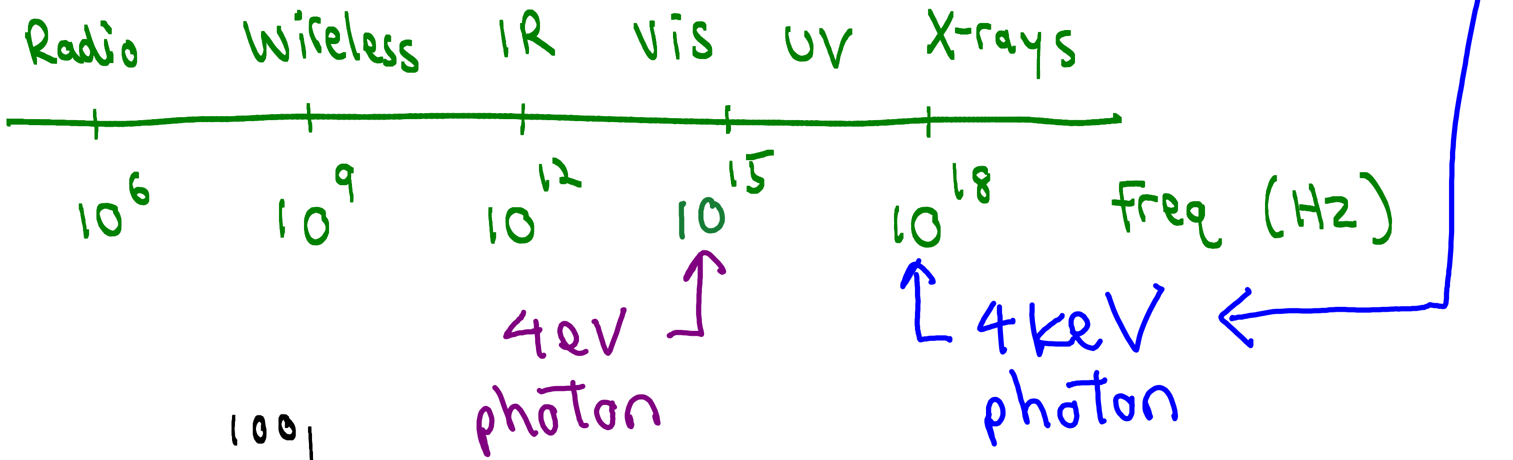
A. Basic geometry





(16.3)

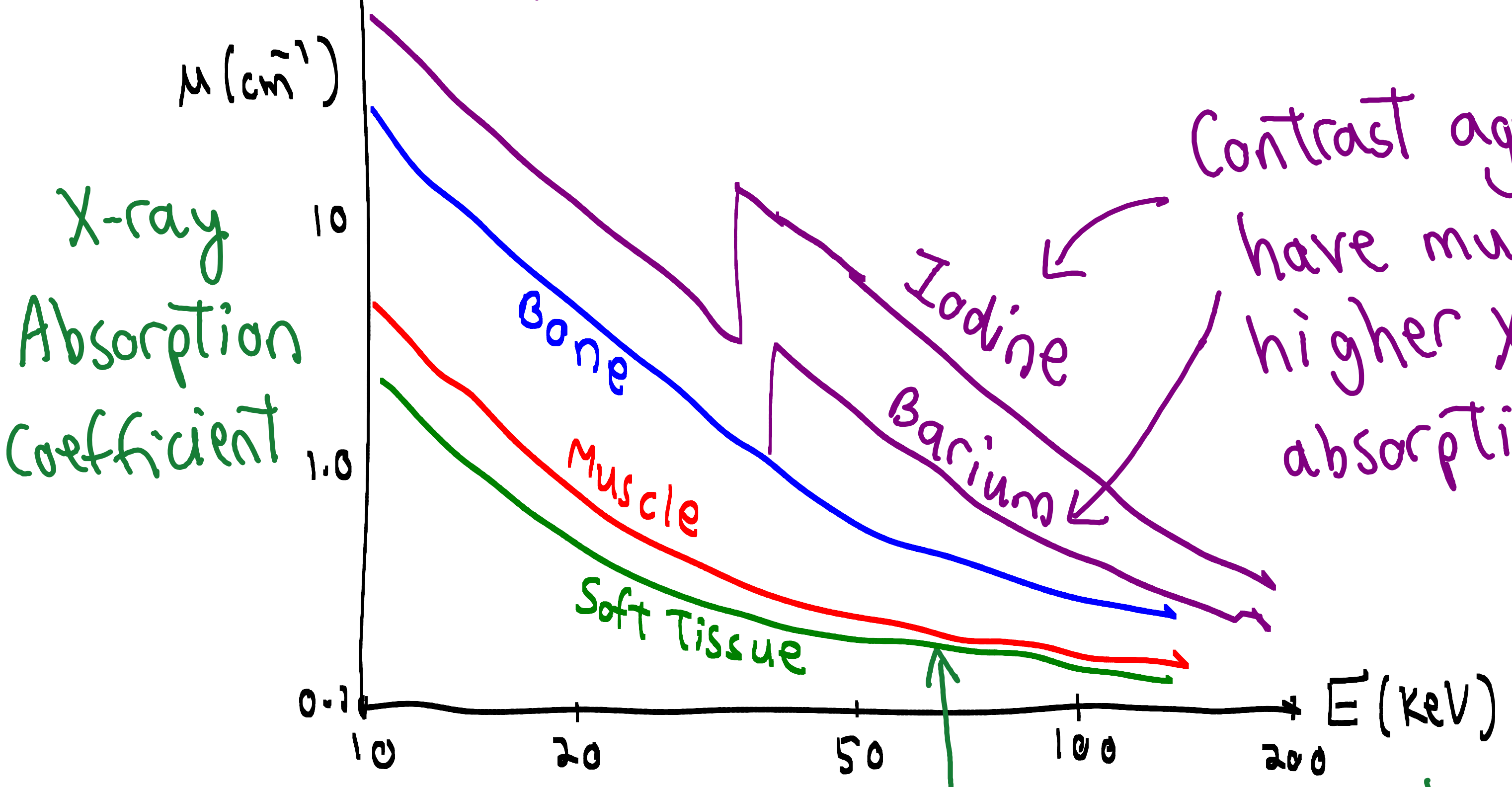
- X-rays: Electromagnetic Spectrum



X-ray photons have very high energy!

- Soft X-rays (~120 eV → 12 keV)
- Hard X-rays (~12 keV → 120 keV)

Most diagnostic imaging

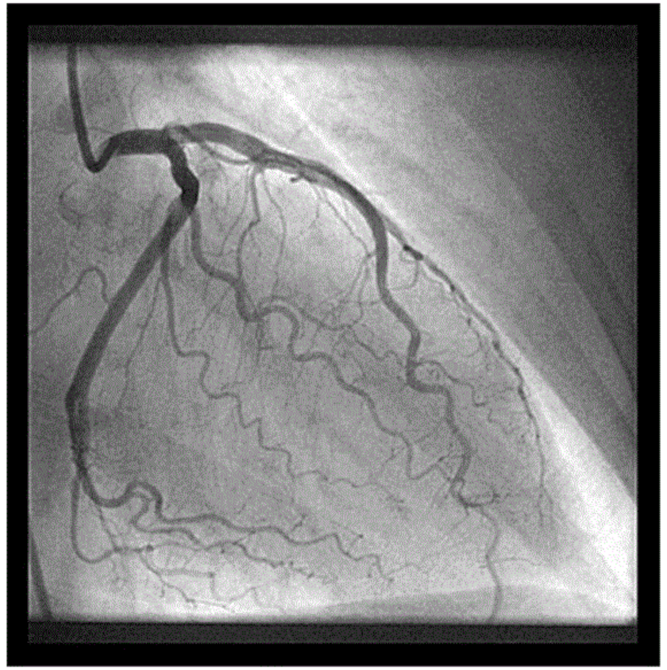


Contrast agents have much higher X-ray absorption!

Soft tissue has low X-ray absorption!

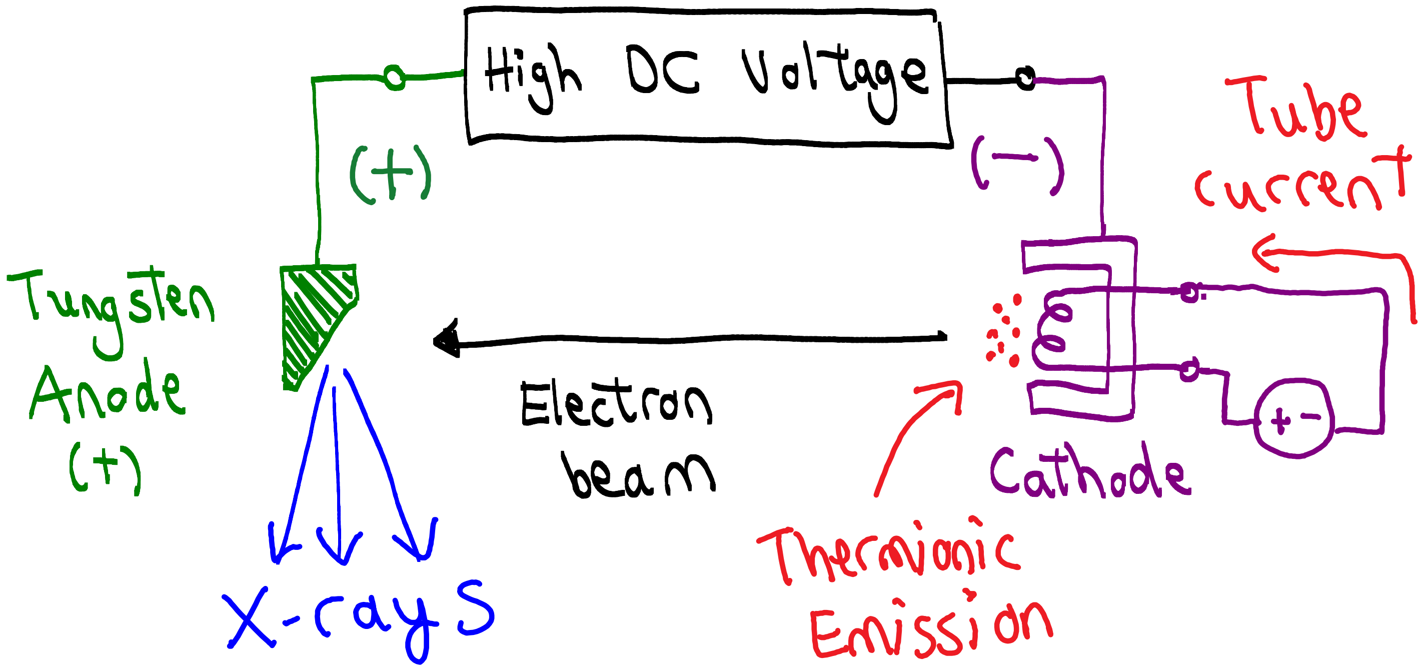
GI Tract (using Barium)

Angiography (using Iodine)



C. X-ray Source ← Coolidge Tube

- X-rays are produced when electrons slam into the tungsten anode



- **User selectable parameters**

① Tube Voltage (kV_p) ← Max photon energy

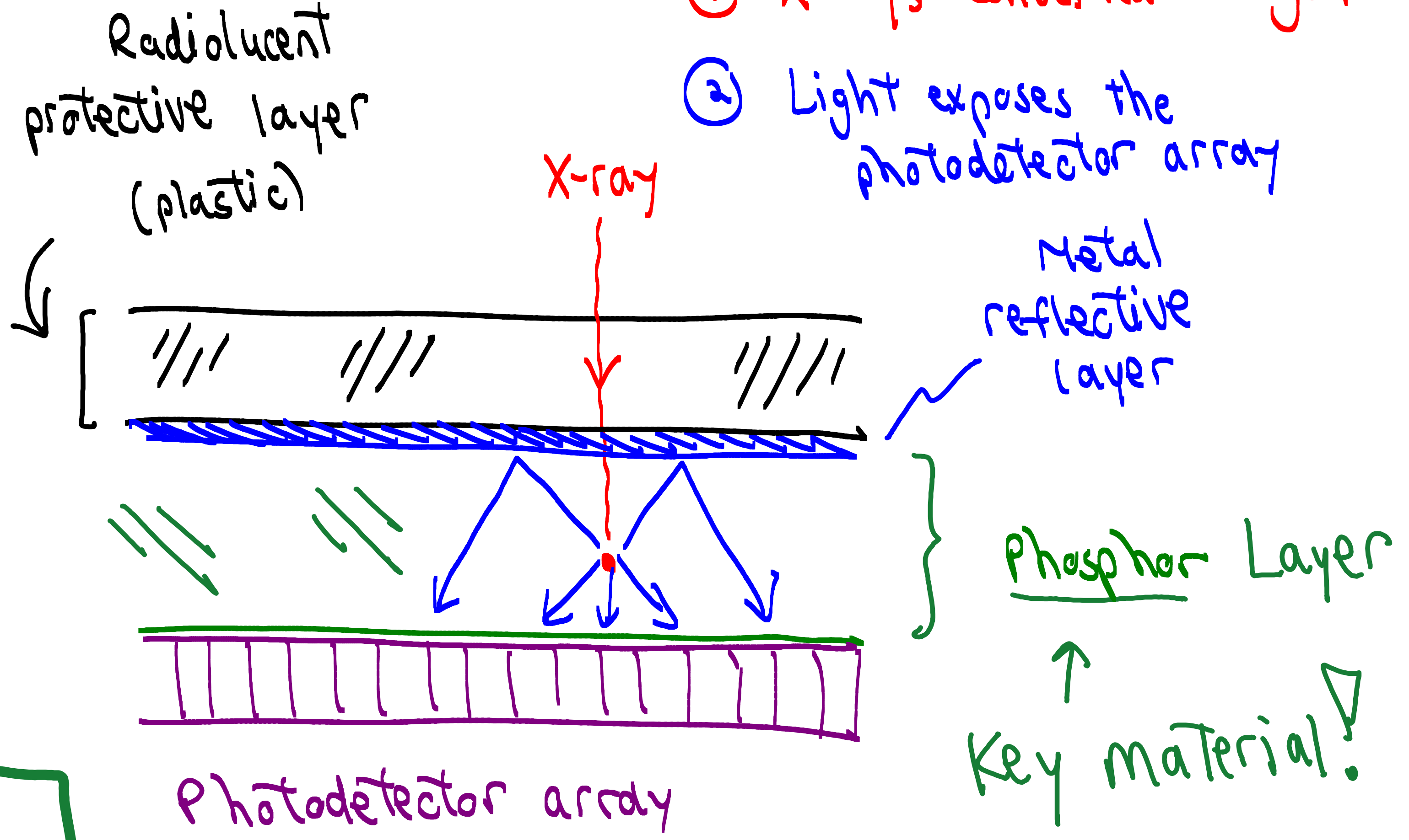
② Tube current (mA) ← # of X-rays (intensity)

③ Exposure Time (ms) ← Image quality vs dose

D. X-ray Detectors ← Two step process:

① X-rays converted to light

② Light exposes the photodetector array



- Calcium Tungstate ($CaWO_4$)
- Gadolinium Oxysulfide (Gd_2O_2S)
- Lanthanum Oxybromide ($LaOBr$)

(16.5)

General Radiology

Canon

Dental X-rays

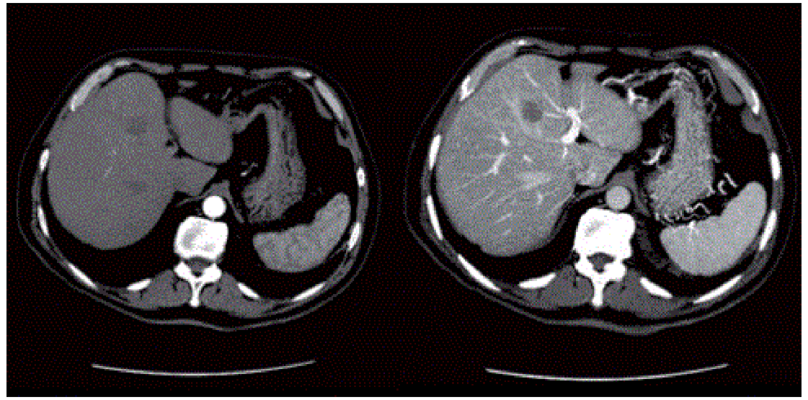
atlanticavenuedental

Detector array?

3. Computed Tomography (CT)

(16.6)

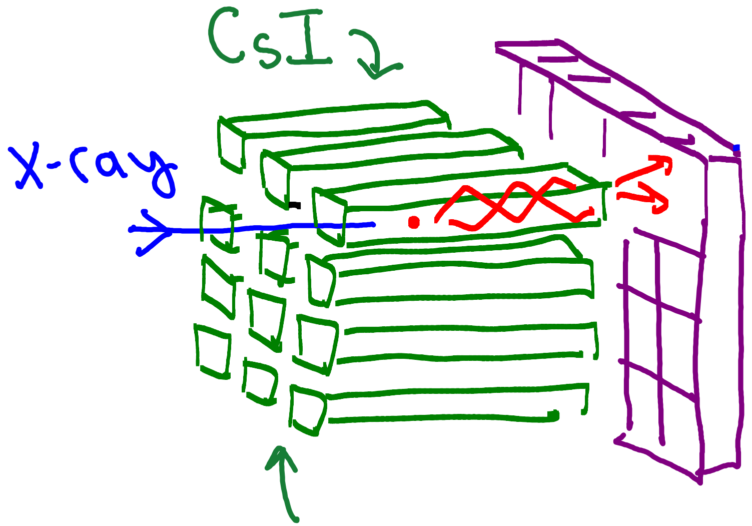
- Unlike projection radiography, computed tomography produces <u>cross-sectional</u> images



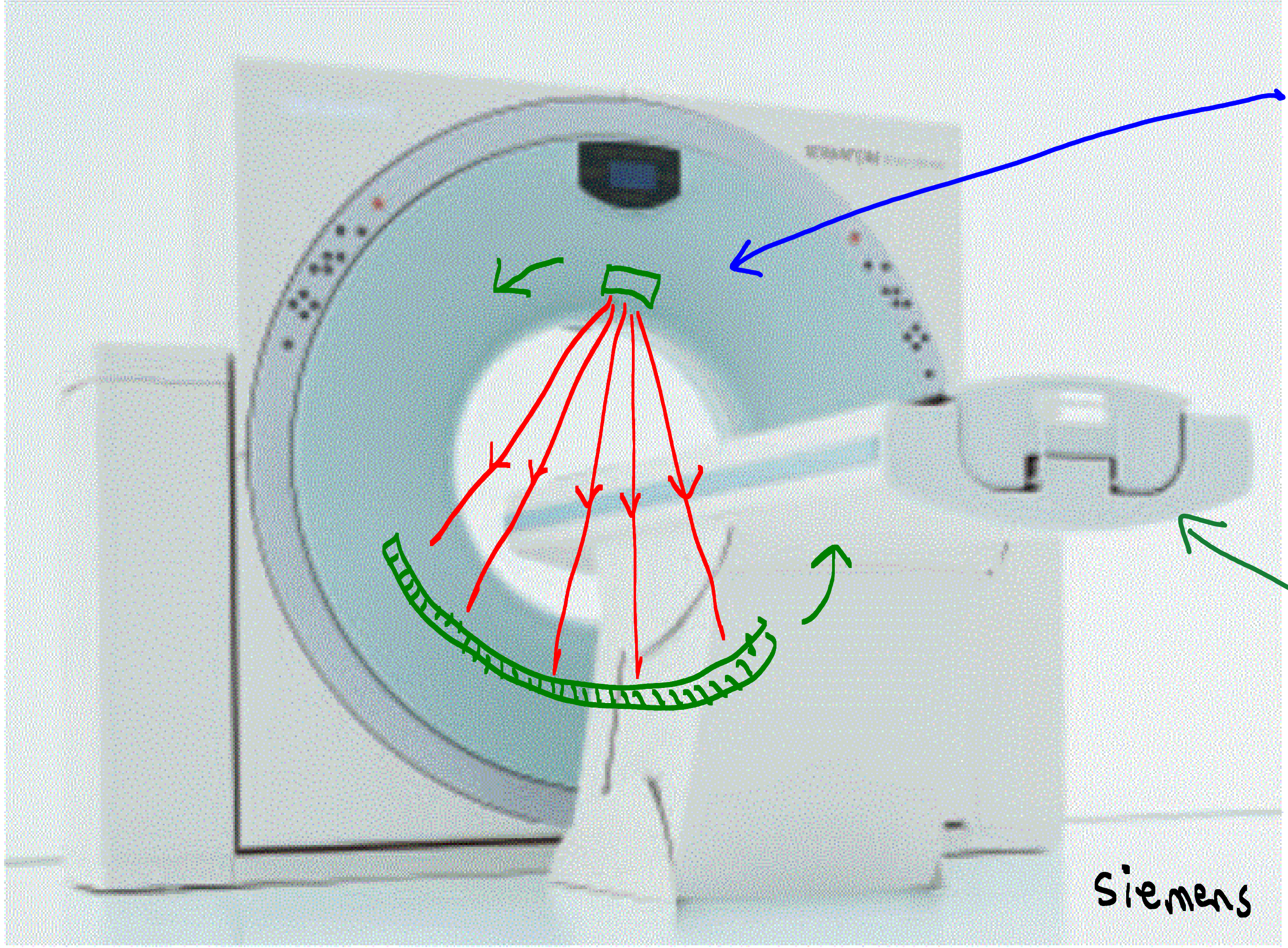
Images show the actual X-ray attenuation coefficient!

- <u>CT Detector Arrays</u>:

(cesium Iodide)



~1x1 mm for multi-slice CT



- <u>Gantry</u>

Holds X-ray tube + <u>detector array</u>

~1 rotation per second

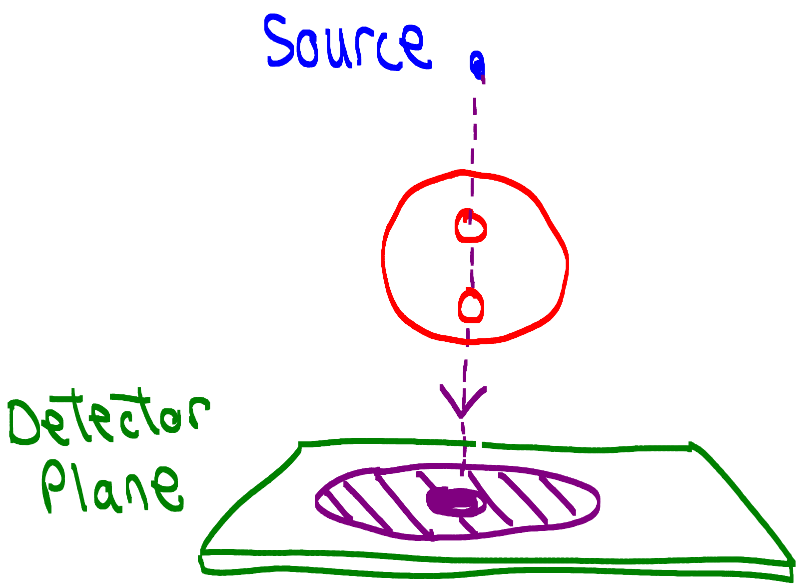
Bore size ≳ 50 cm

- <u>Patient Table</u>

Translates patient during volume acquisition

Typically ~10 mm/sec

Projection Radiography

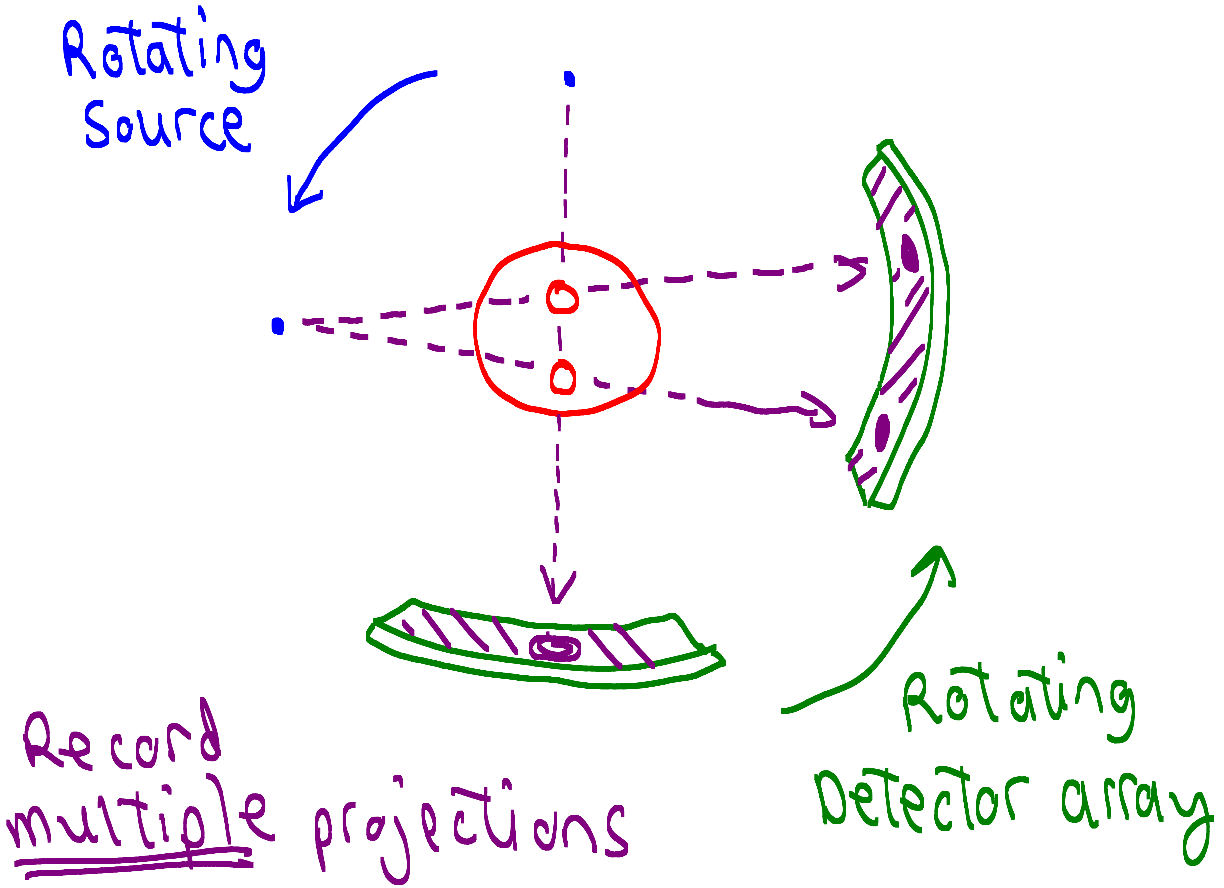


→ Single projection of entire volume

⇒ No depth resolution!
☹

VS.

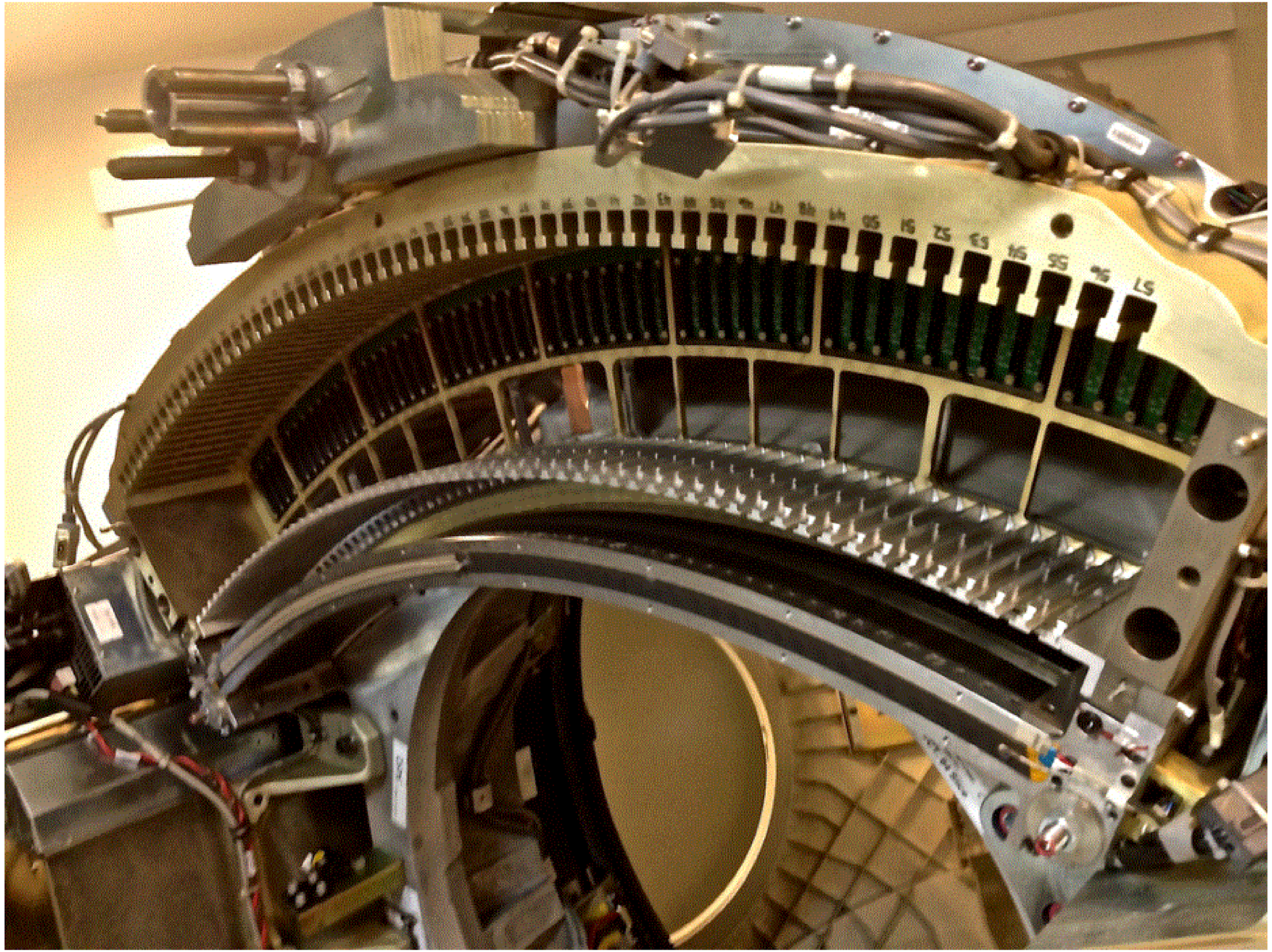
Computed Tomography (CT)



→ Record multiple projections at many angles

⇒ Projections are processed to reconstruct a cross-sectional slice

☺



(Jaime Salazar → flickr.com)

4. MRI Magnetic Resonance Imaging

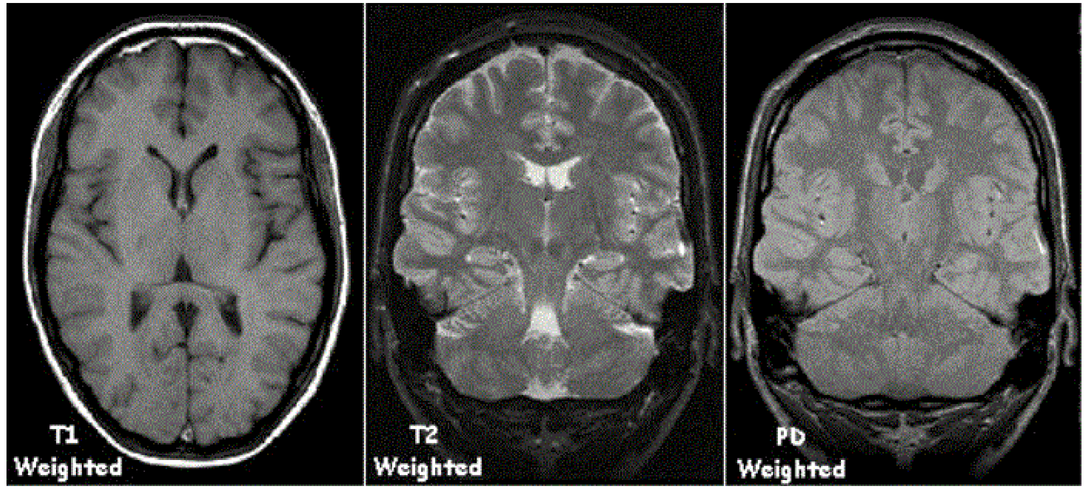
(16.9)

Key concepts:

① Tissue can be magnetized

② Magnetization strength and duration depend on tissue type

GE



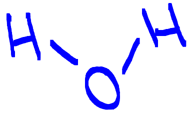
wikipedia

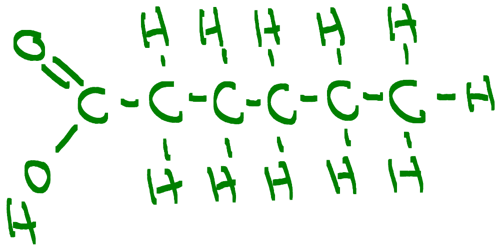
T_1 weighting T_2 weighting Proton Density weighting

3 basic types of MRI contrast

* MRI images show the distribution of hydrogen nuclei in the body.

↑ water, fat, ...

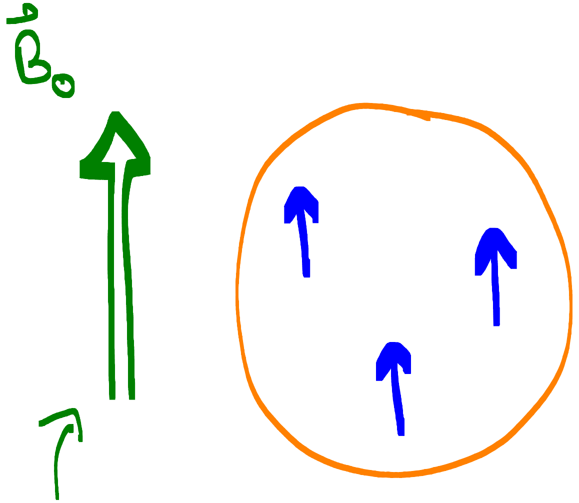




Q: How to measure tissue magnetization $\vec{M}(x,y,z)$?

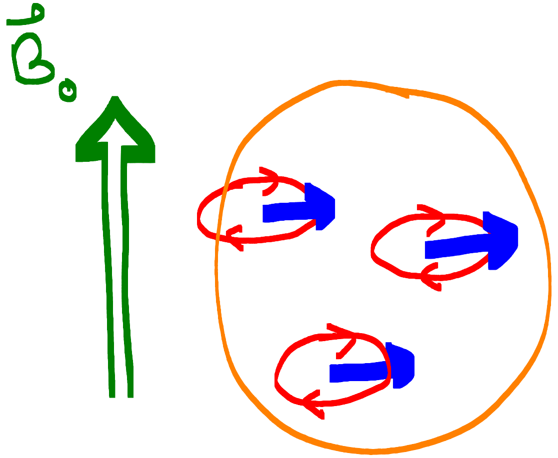
A: Basically a 3-step process

① Magnetize the body to create $\vec{M}$



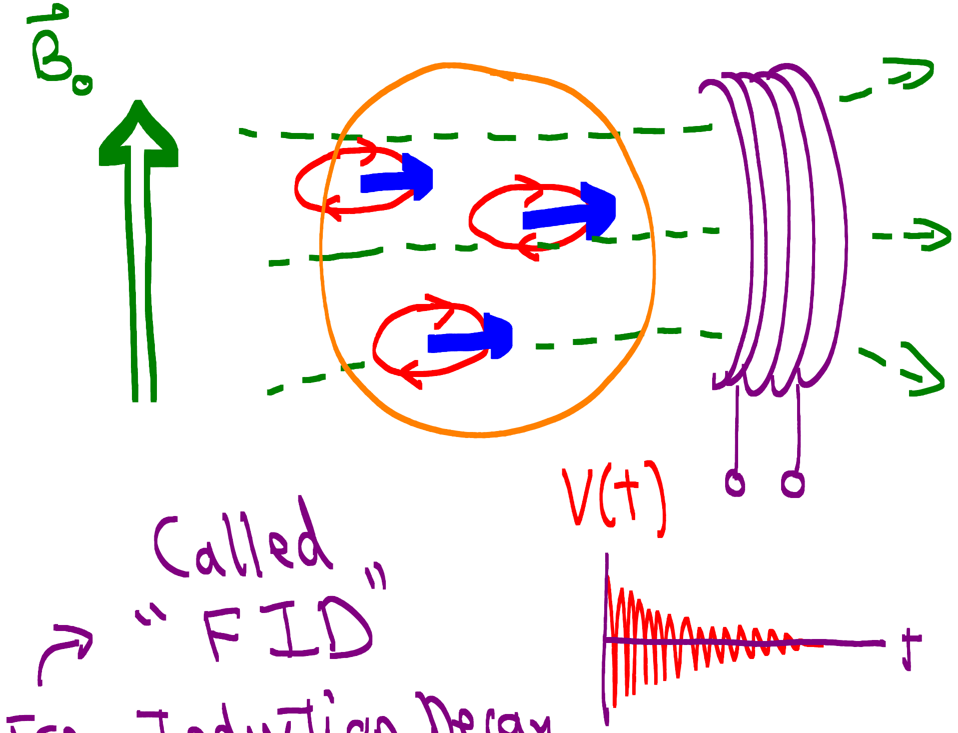
Sometimes called "polarizing" field

② Tip $\vec{M}$ away from $\vec{B}_0$ to induce resonance



Rotation is called "precession"

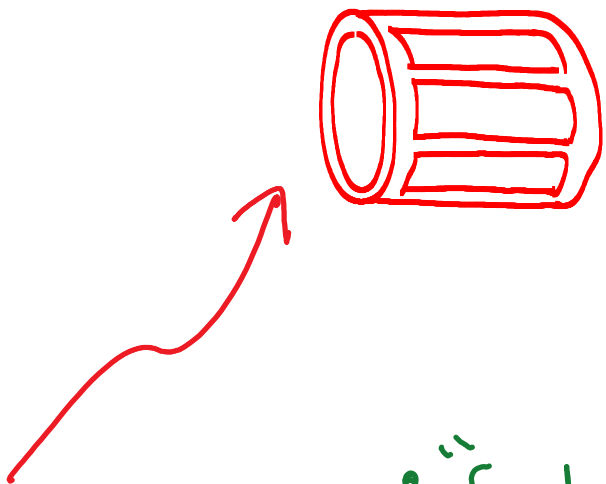
③ Record time-varying response of $\vec{M}$



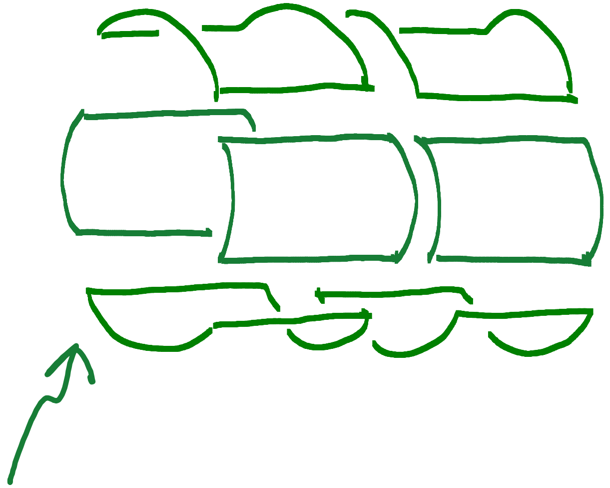
Called "FID"

Free Induction Decay

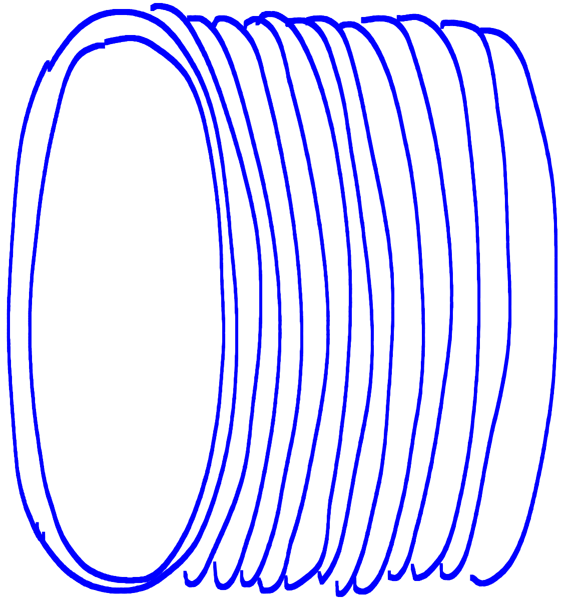
System Diagram



RF coils



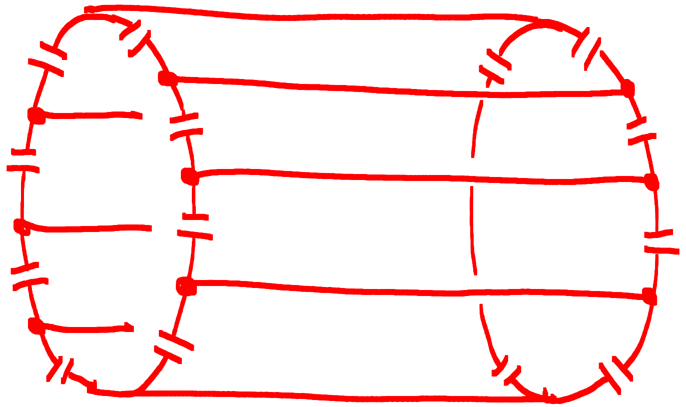
Gradient Coils



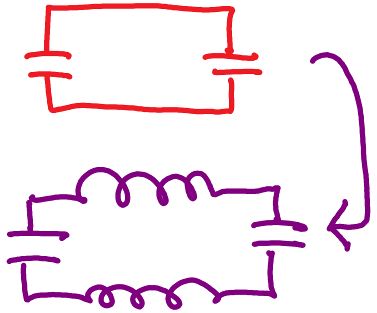
MAIN MAGNET

$B_0 = 1.5$ or 3 Tesla

- Common design is the bird cage coil



Typically 8 or 16 sections



At MHz Freq

- "Saddle coils" produce linearly varying B-field
- Pulsed operation

→ Magnetic torque produces loud "knocking" sounds!

Big solenoid of Niobium-Titanium wire

→ Super conductor when T<9.5K

→ Liquid helium cooling (4.2K)

5. Ultrasound

(16.12)

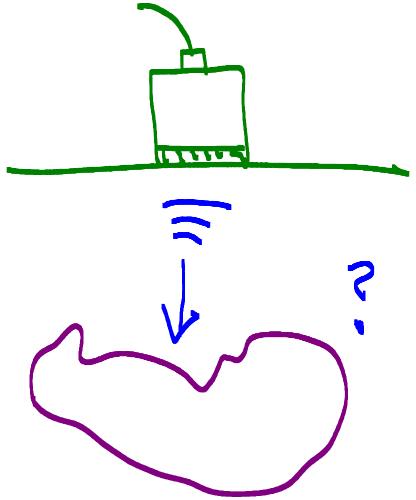
- Key Concept

✱ Echo ranging technique

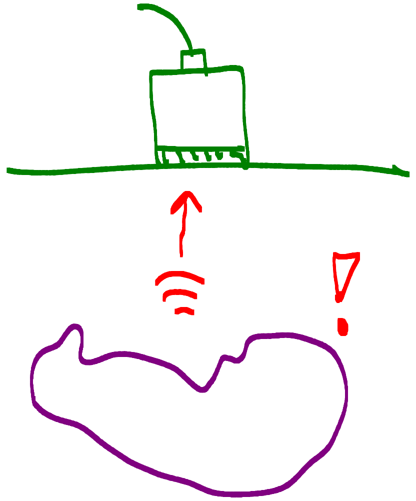
- Arrival time → Object distance
- Amplitude → Acoustic reflectivity

↑ Image Contrast

① Transmit a pulse into body



② Receive echoes



Philips

- Frequency : Typically a few MHz

$$f = \frac{c}{\lambda} = \frac{1.54\ \text{mm}/\mu s}{1\ \text{mm}} = 1.54\ \text{MHz}$$

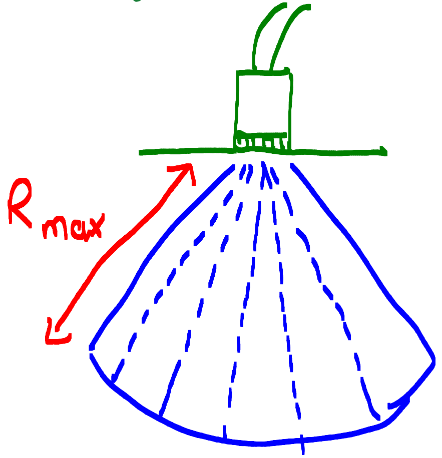
want ~mm resolution!

- Imaging Time :

Typical $R_{max} = 150$ mm
#beams $= N = 150$

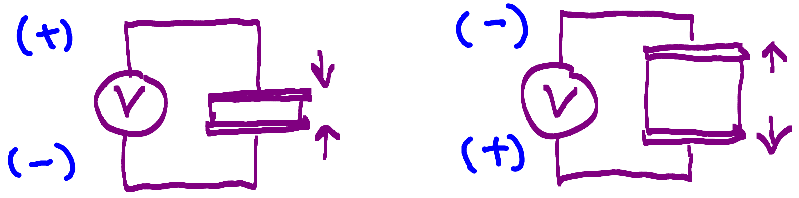
$$T = N \times \frac{2R_{max}}{c}$$
$$= 150 \times \frac{2 \times 150\ \text{mm}}{1.5\ \text{mm}/\mu s}$$
$$= 150 \times 200\ \mu s$$
$$= 30\ \text{ms}$$

~33 Hz frame rate!



Ultrasound Transducers

- For MHz frequencies, use the piezoelectric effect



- Commonly used materials

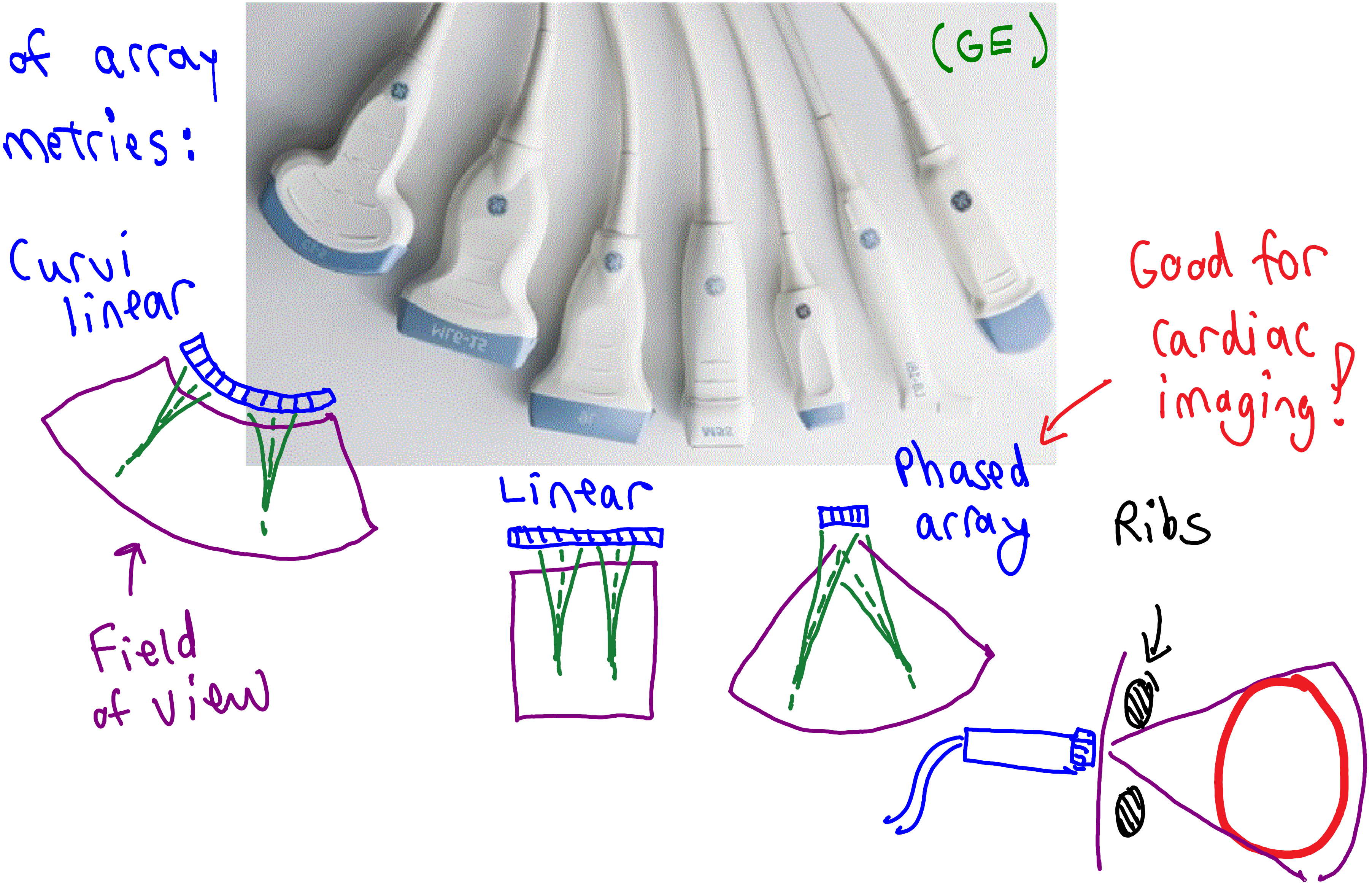
☆ Lead zirconate titanate (PZT)

☆ Single Crystal PMN-PT

Lead Magnesium Niobate Titanate

- Clinical systems use transducer arrays to quickly scan ultrasound beams across the field of view.

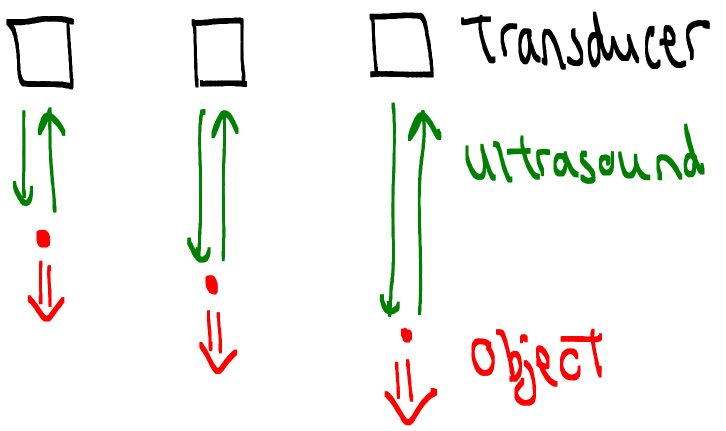
- Lots of array geometries:



• Color Flow Imaging

A moving object produces an echo arrival time that is NOT constant.

Ex:

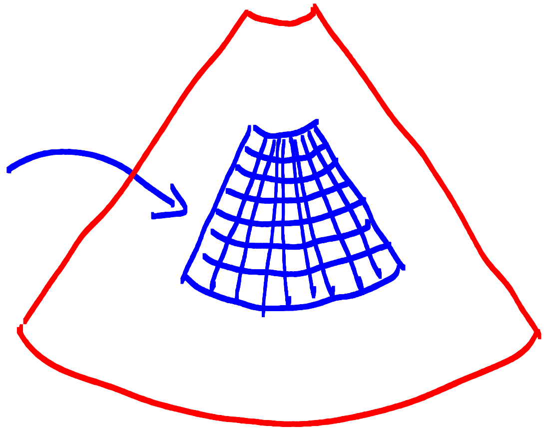


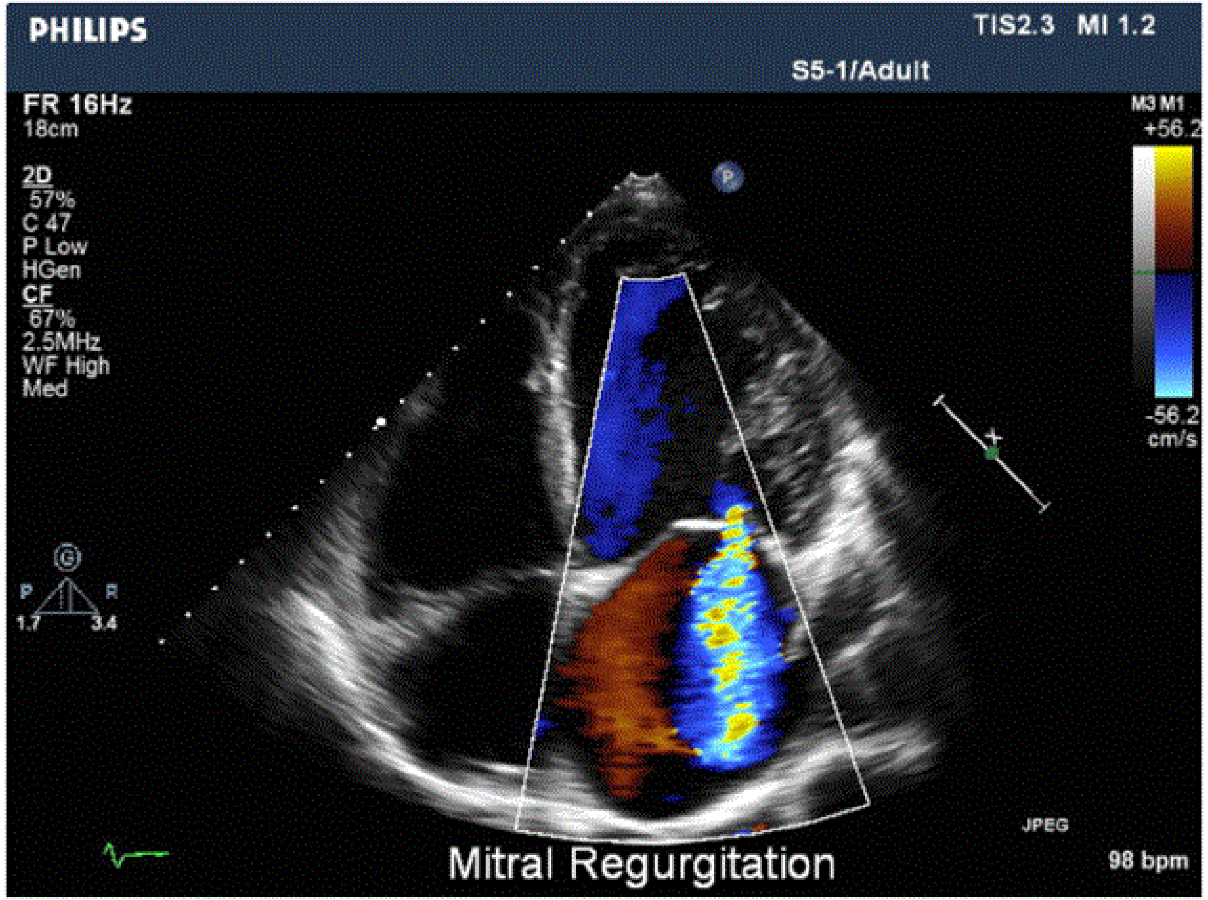
⇒ "Pulsed wave Doppler" monitors the echos to determine velocity at one point

⇒ "Color Flow Imaging" performs pulsed wave Doppler at multiple points

✲ Lots of processing power required to do this!

Perform pulsed wave Doppler in each pixel!





Mitral Regurgitation

(16.15)

- Commercial systems come in many flavors...

Cell Phone size

Notebook size

Cart Size

(GE)