Imaging of cancer

Imaging of Cancer:

How various imaging modalities work

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Imaging of Cancer

- Imaging is a key element of:
  - Screening (e.g. lung cancer, breast cancer)
  - Staging (has it spread locally? Metastasized?)
  - Monitoring of treatment (Better or worse?)
  - Recurrence (Has it come back?)
  - Prognosis (What will happen?)

The Main Imaging Devices

- Computed Tomography (CT)
- Magnetic Resonance Imaging (MRI)
- Ultrasound (US)
- Single Photon Emission Computed Tomography (SPECT)
- Positron Emission Tomography (PET)
- Optical Imaging

Scanners

They all look the same!

CT

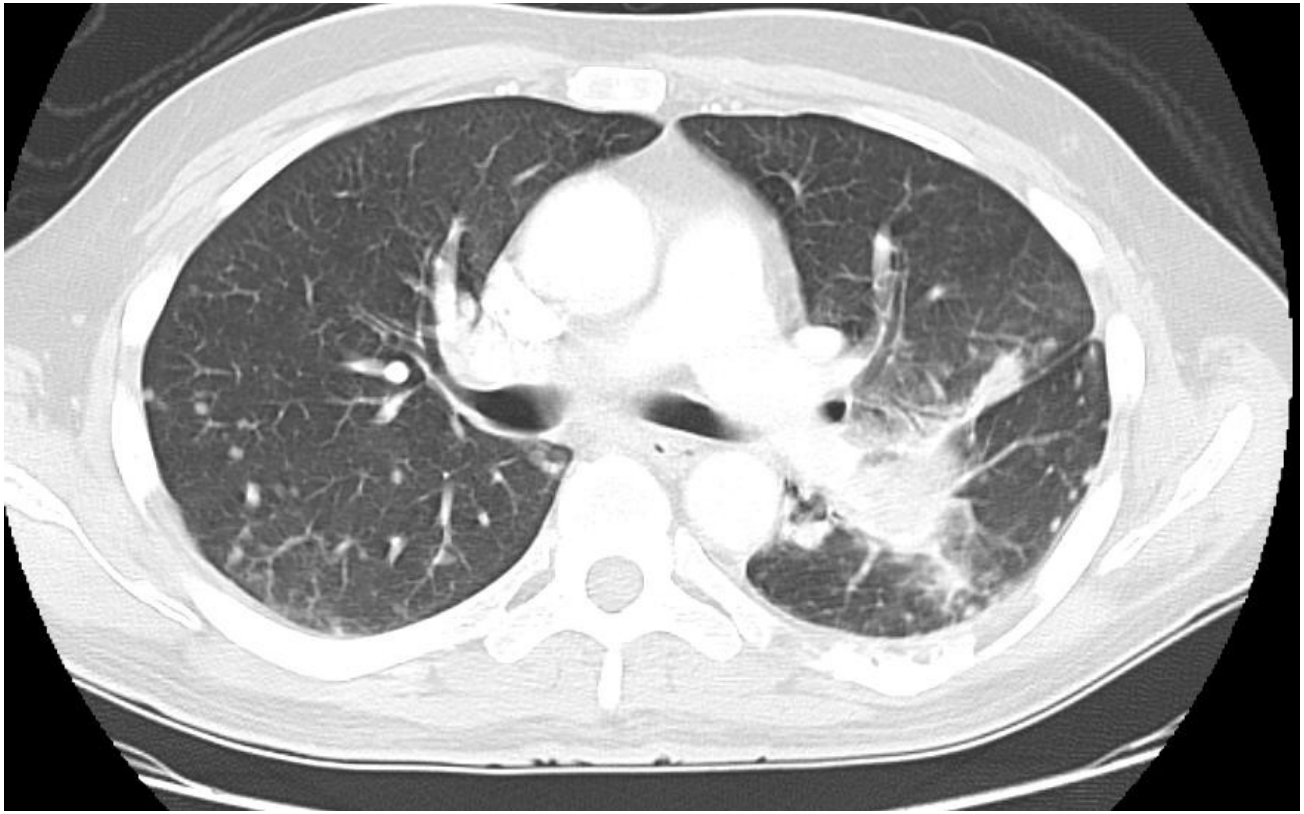
MRI

US

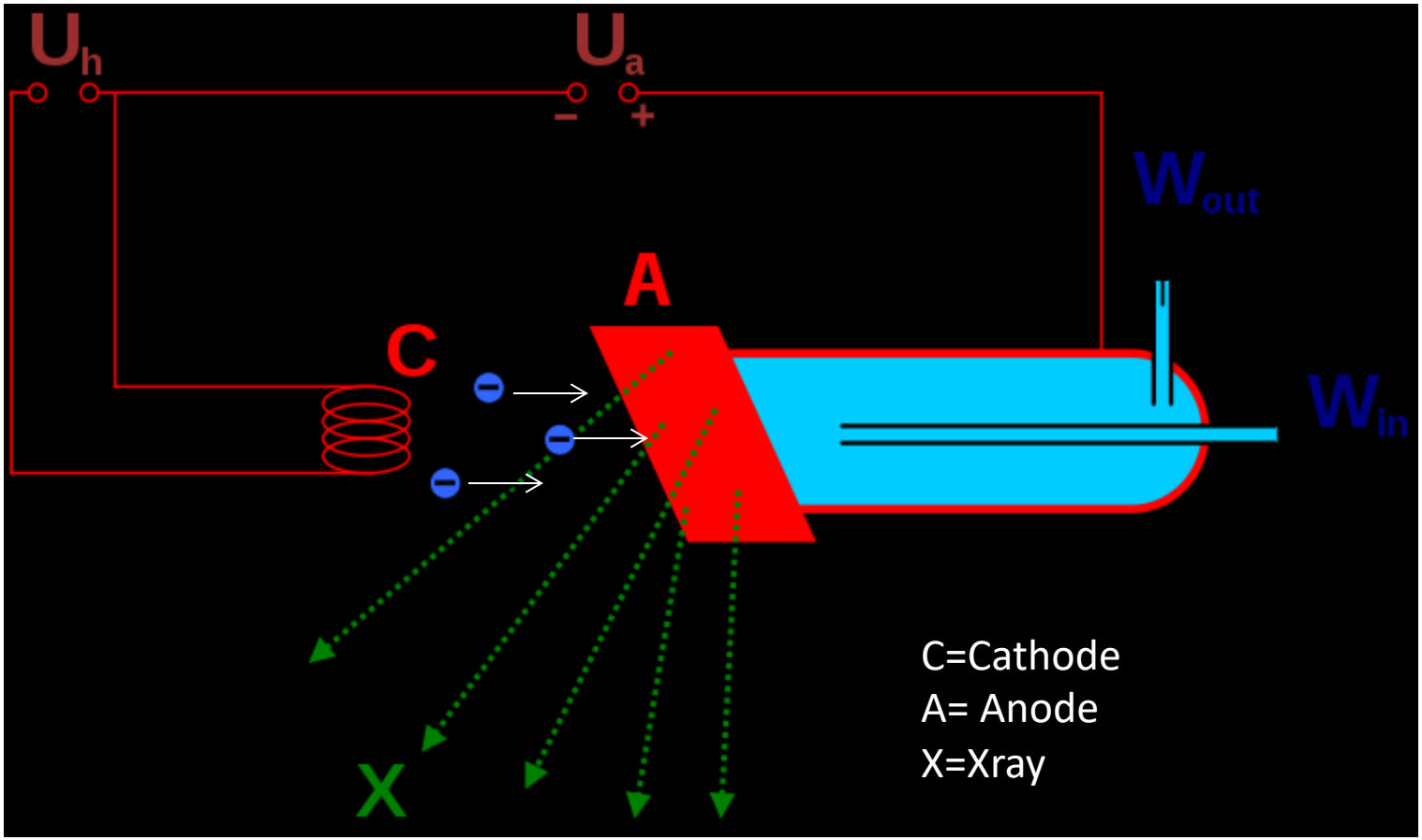
SPECT

PET

Computed Tomography

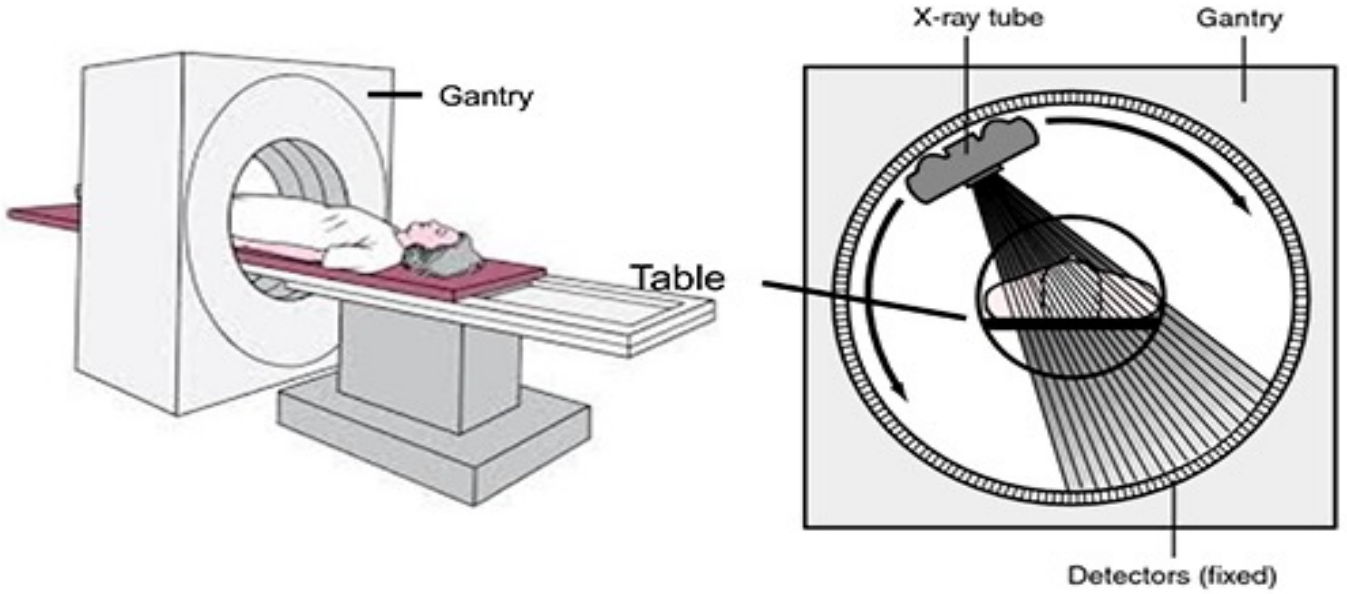


X-ray production: cathode ray tube



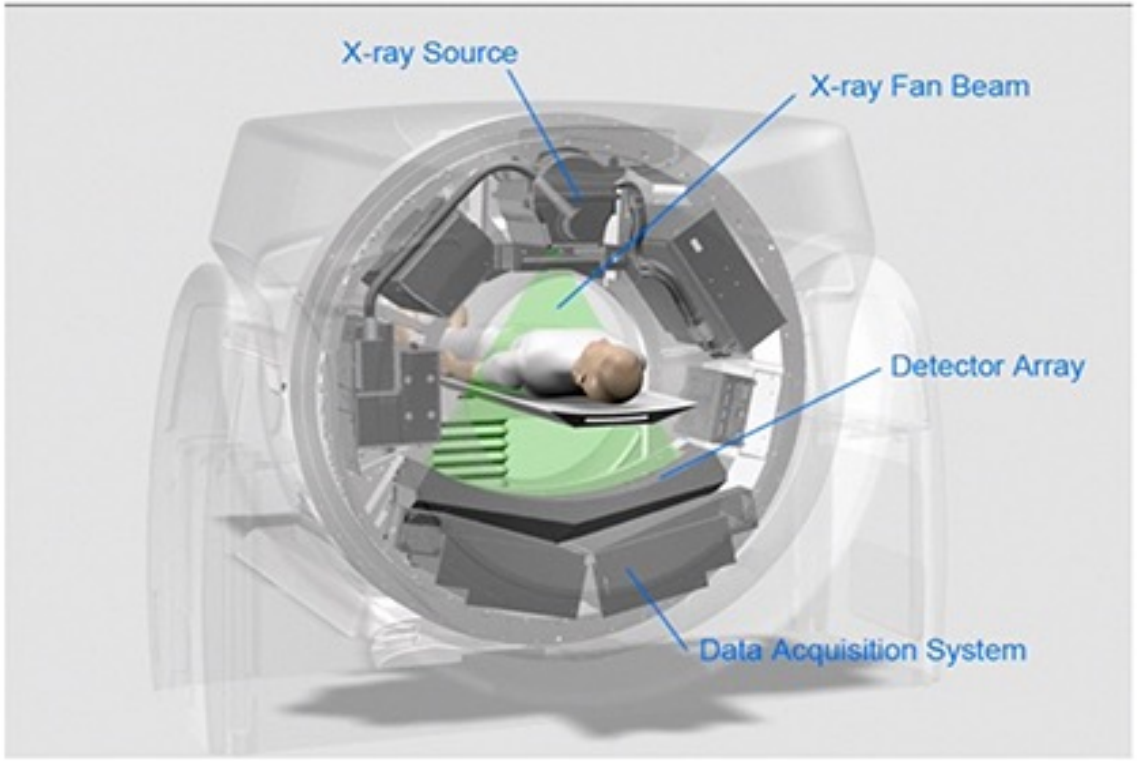
Basics of CT

Basics of CT

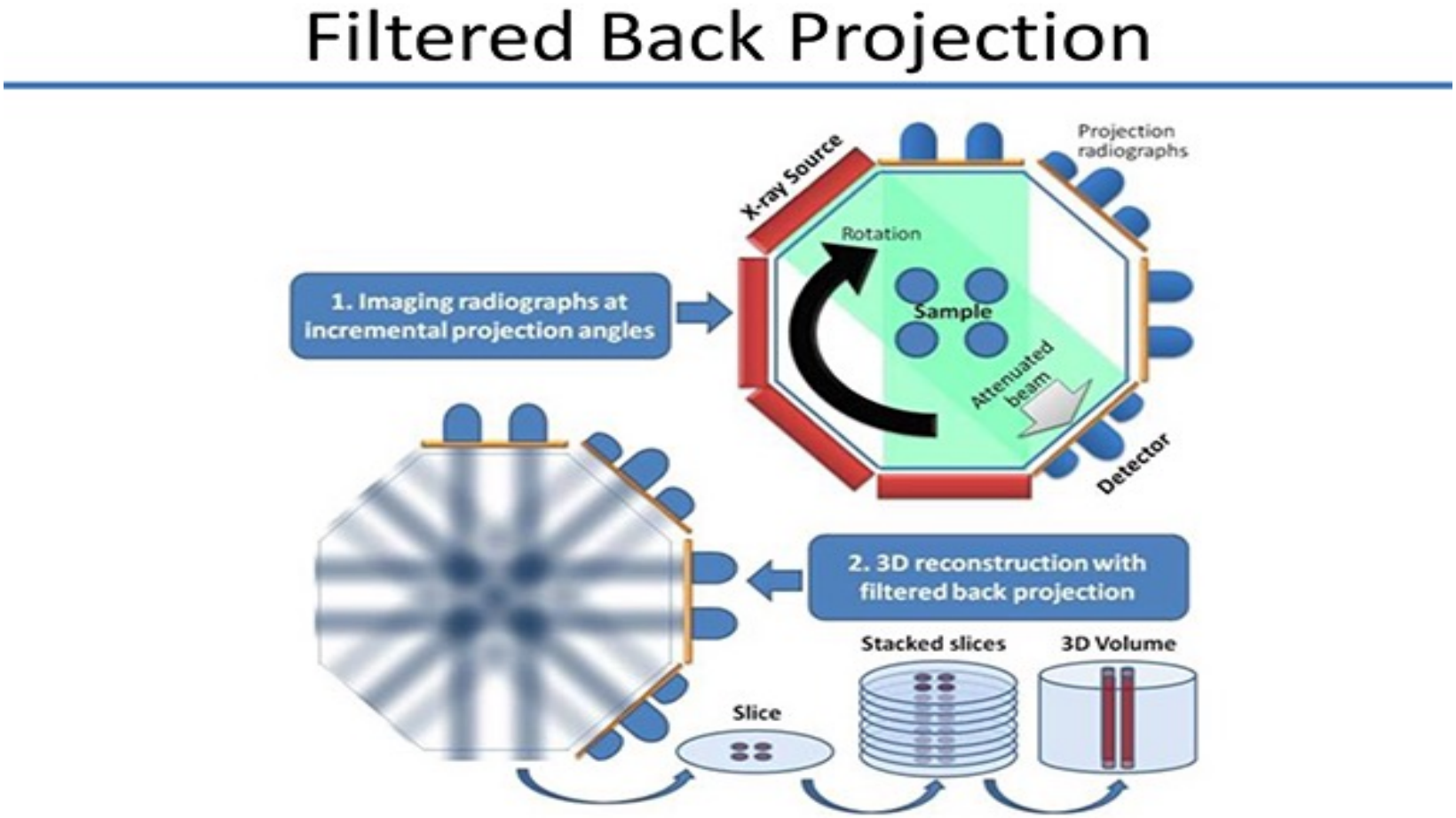


CT scanner

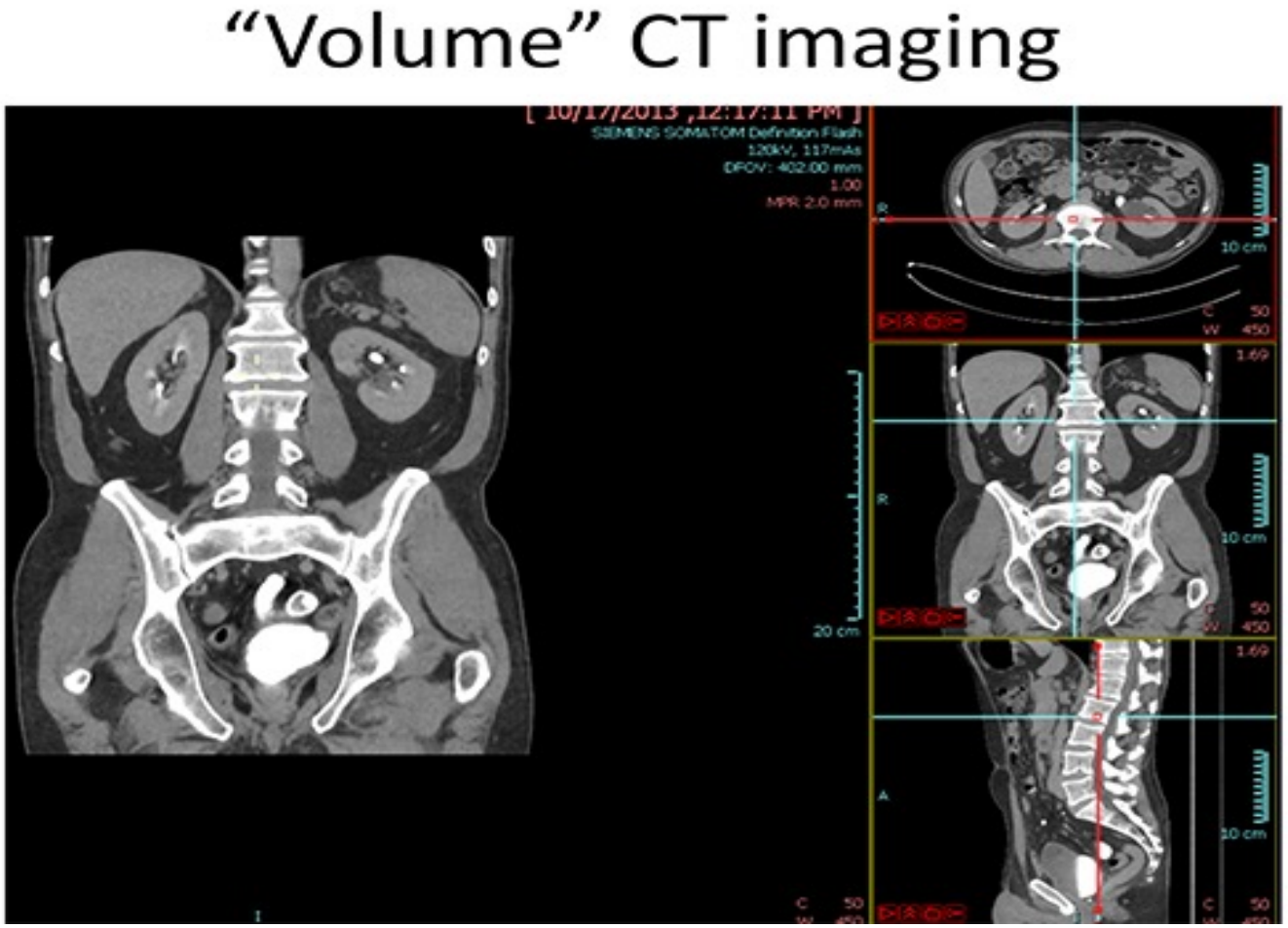
Cross section of a CT Scanner



Filtered back projection

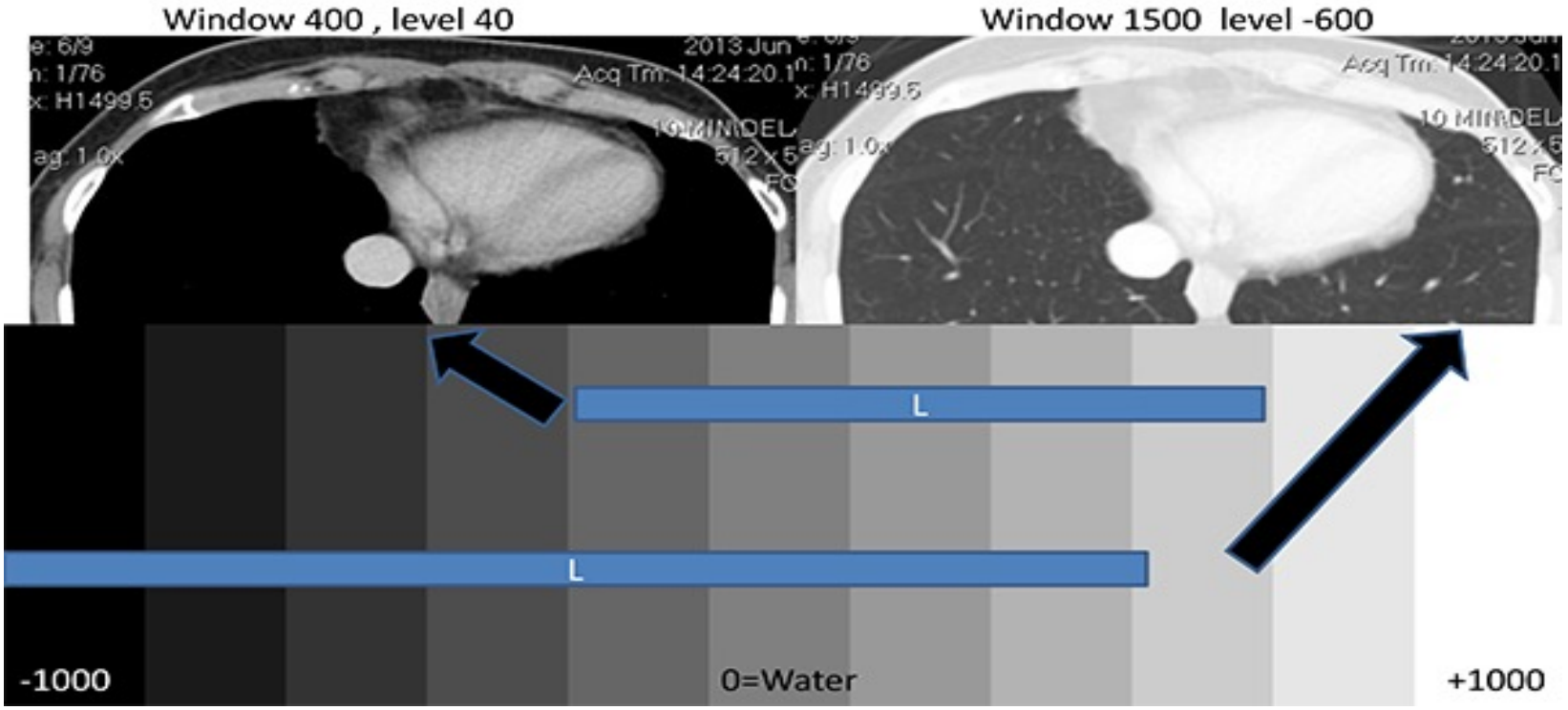


Volume CT imaging



Windowing a CT

"Windowing" a CT: The value of a digital image



Advantages of CT

- Widely available
- Minimal prep (NPO, drink contrast)
- Very rapid (2-3 seconds neck to pelvis)
- High resolution
- Relatively inexpensive

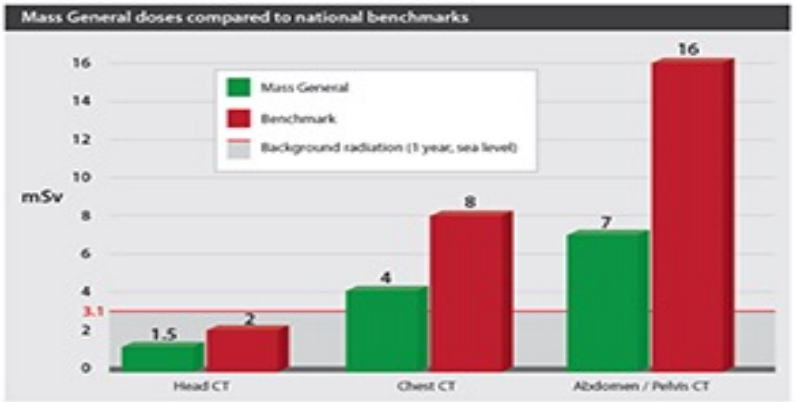
Disadvantages

- **Radiation**
- Often requires iv contrast media
  - Allergic reactions (minimal)
  - Kidney damage (only in high risk patients)
- Anatomic information only

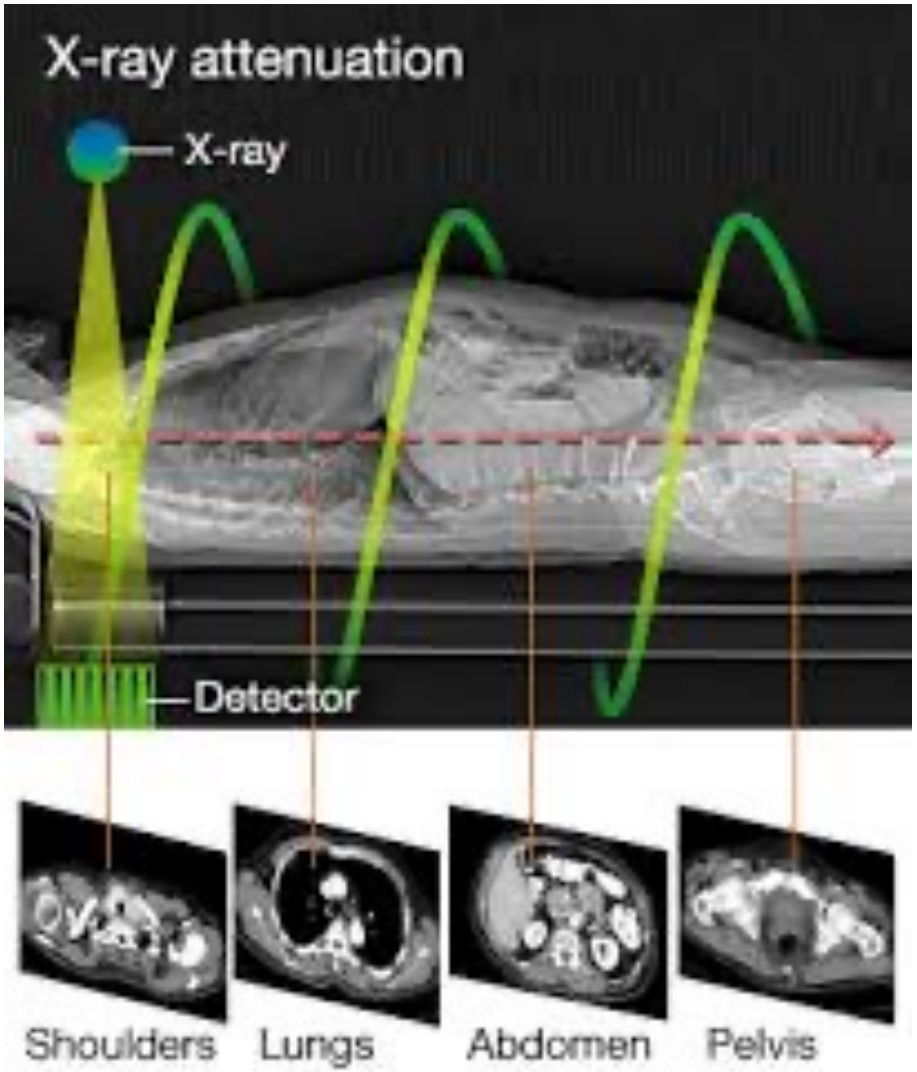
Radiation reduction

Radiation Reduction on CT

Lower kV (energy) x-rays
More sensitive detectors
Better reconstruction algorithms
"Synthetic" images

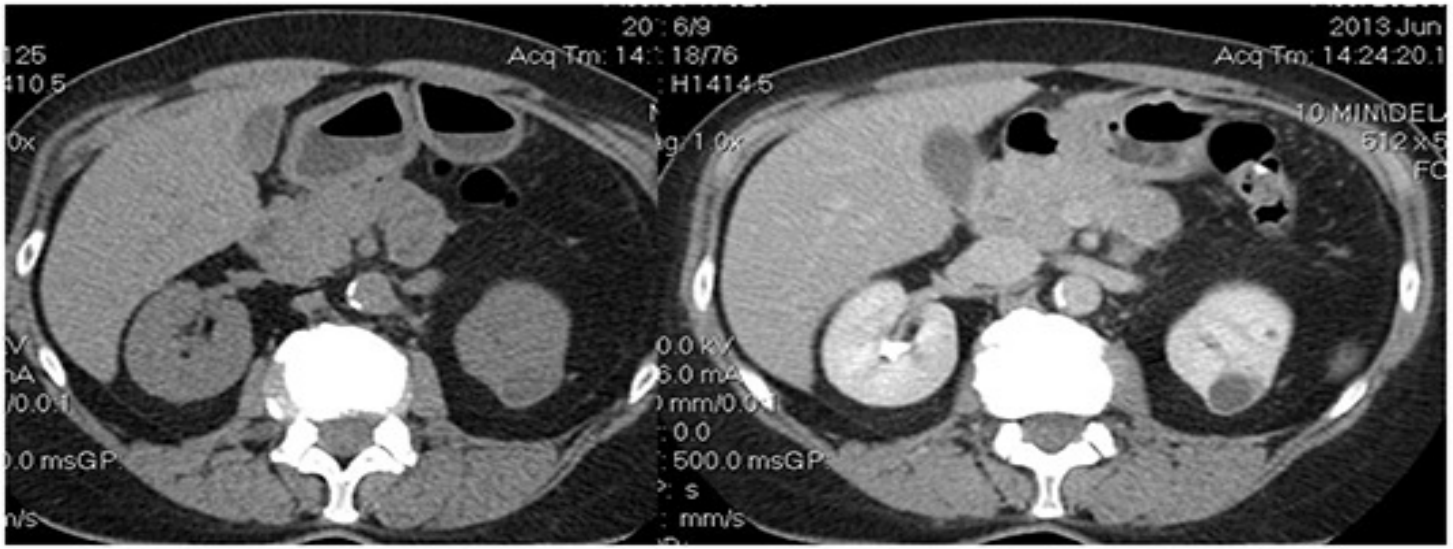


Attenuation differences thru the body mean less radiation for some regions



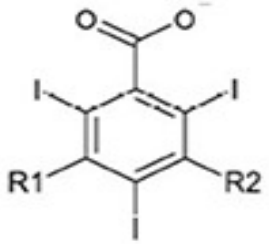
Contrast media

Iodinated Contrast Media

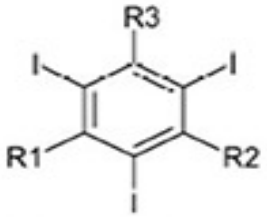


Structures

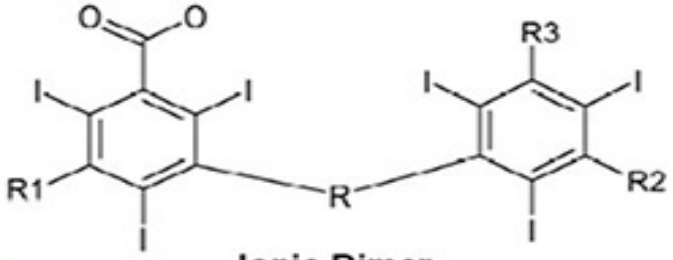
Basic Structures of Contrast Media



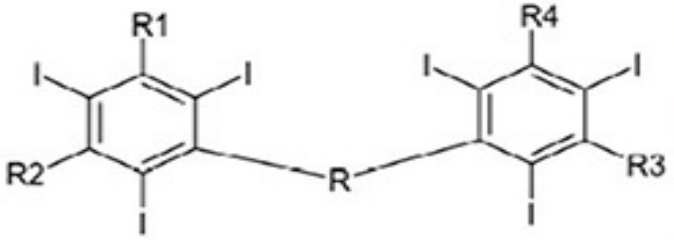
Ionic Monomer



Nonionic Monomer



Ionic Dimer

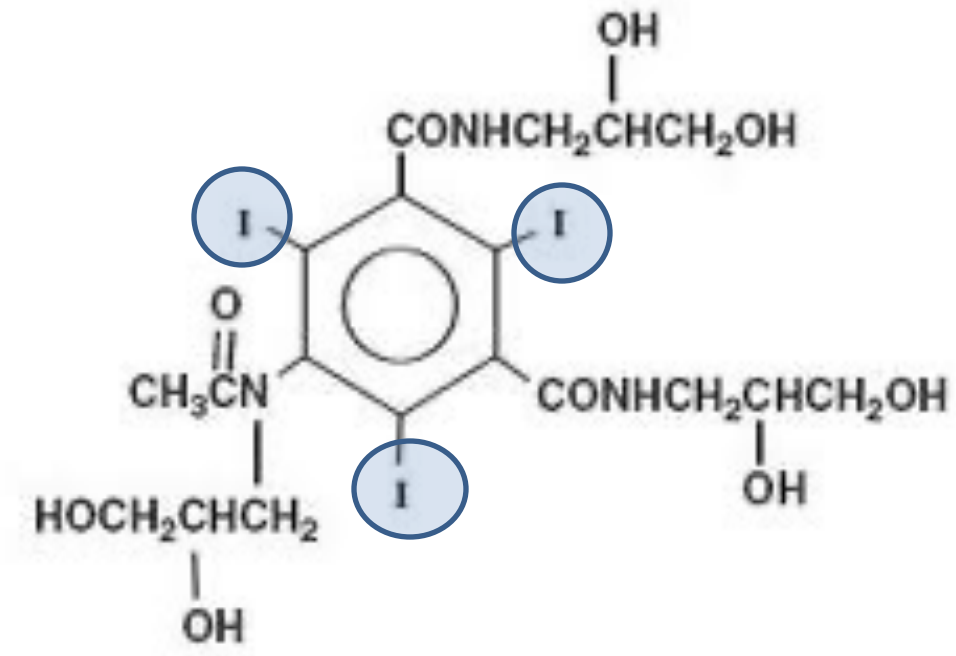


Nonionic Dimer

Voeltz MD, et al. *J Invasive Cardiol.* 2007 Mar;19(3):1A-9A. Review

TCT2009

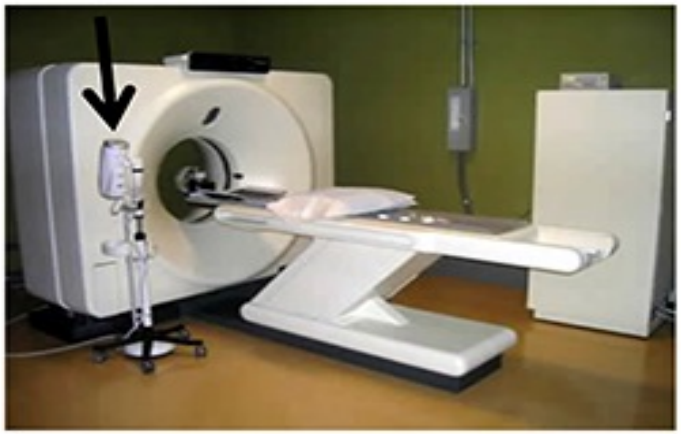
Non ionic Iodinated Contrast



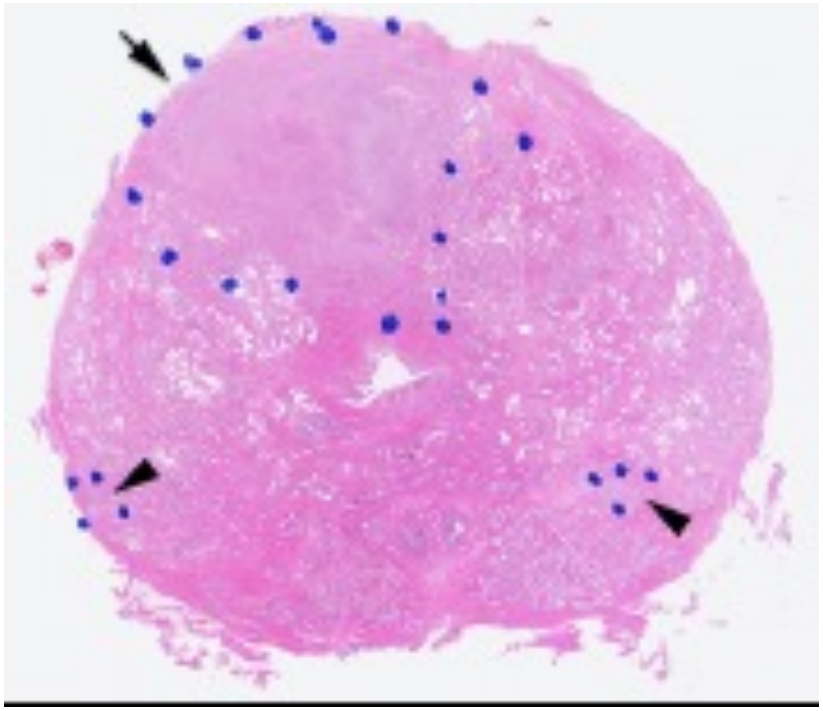
Typical dose 30-45 Grams of Iodine!!!

Iodinated contrast

Iodinated Contrast

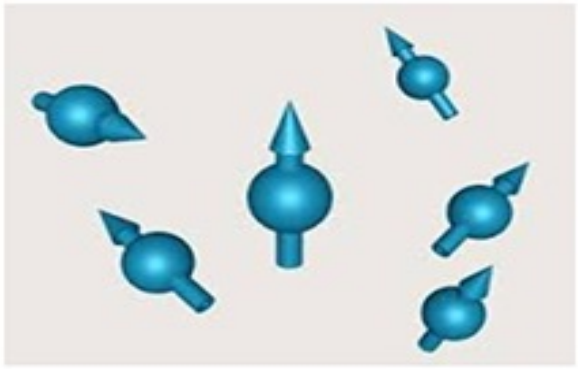


Magnetic Resonance Imaging

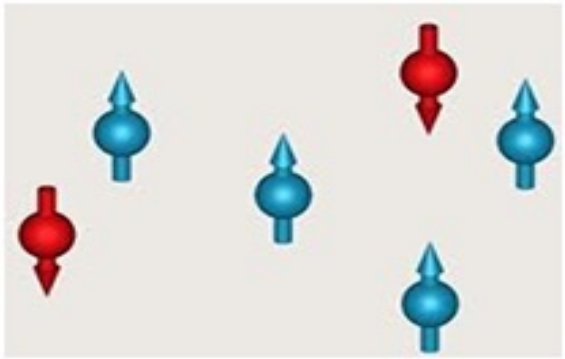


MRI physics

MRI Physics 101

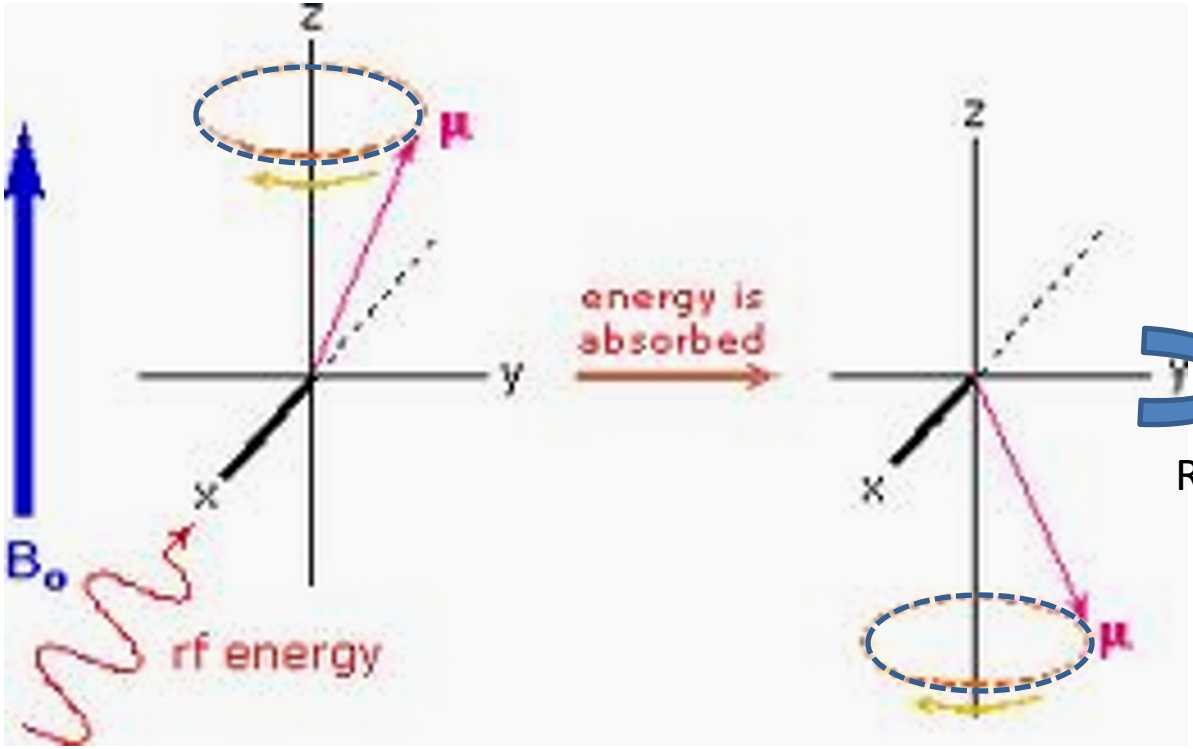


Protons in space: no field

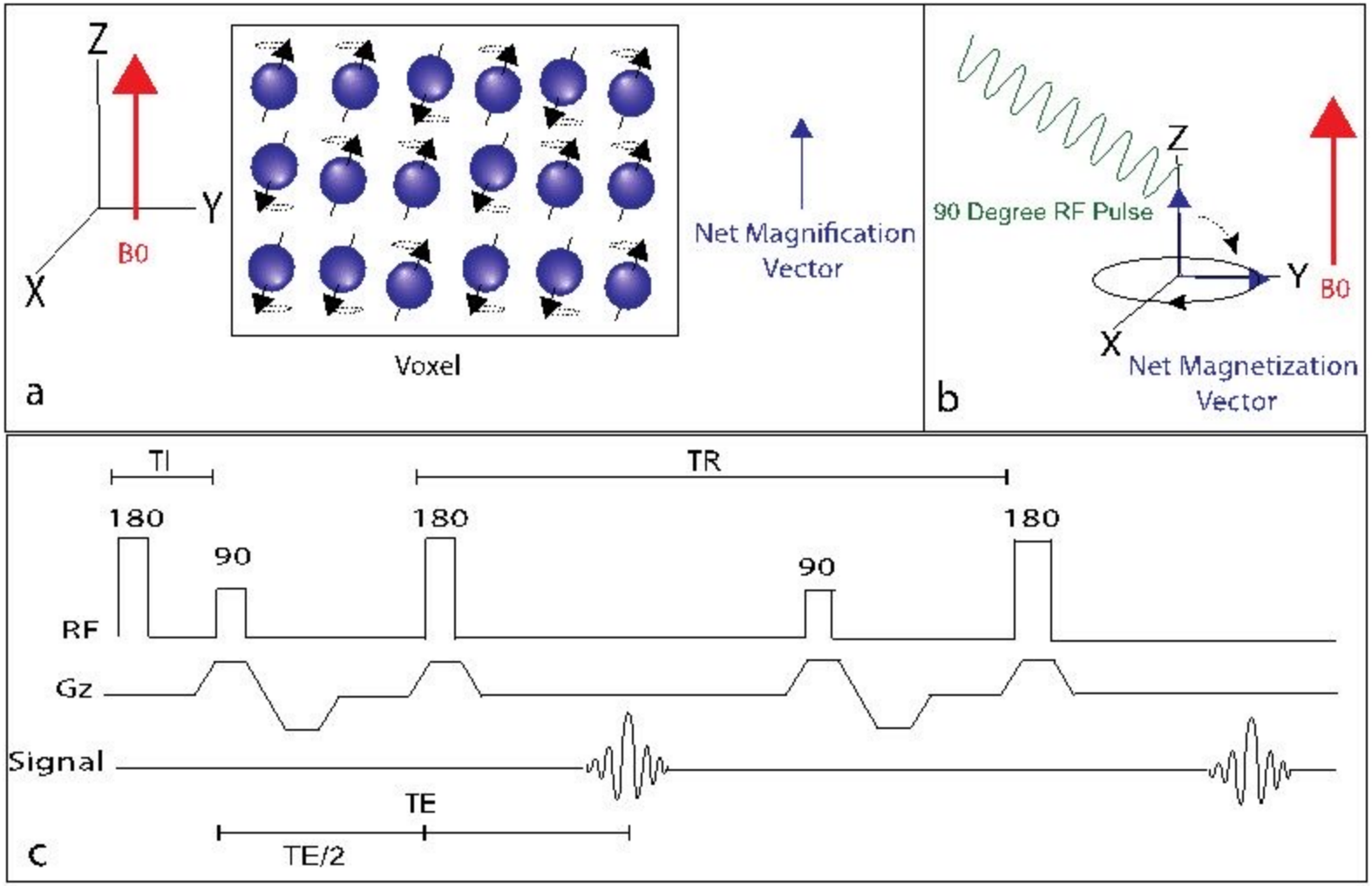


Protons in magnetic field

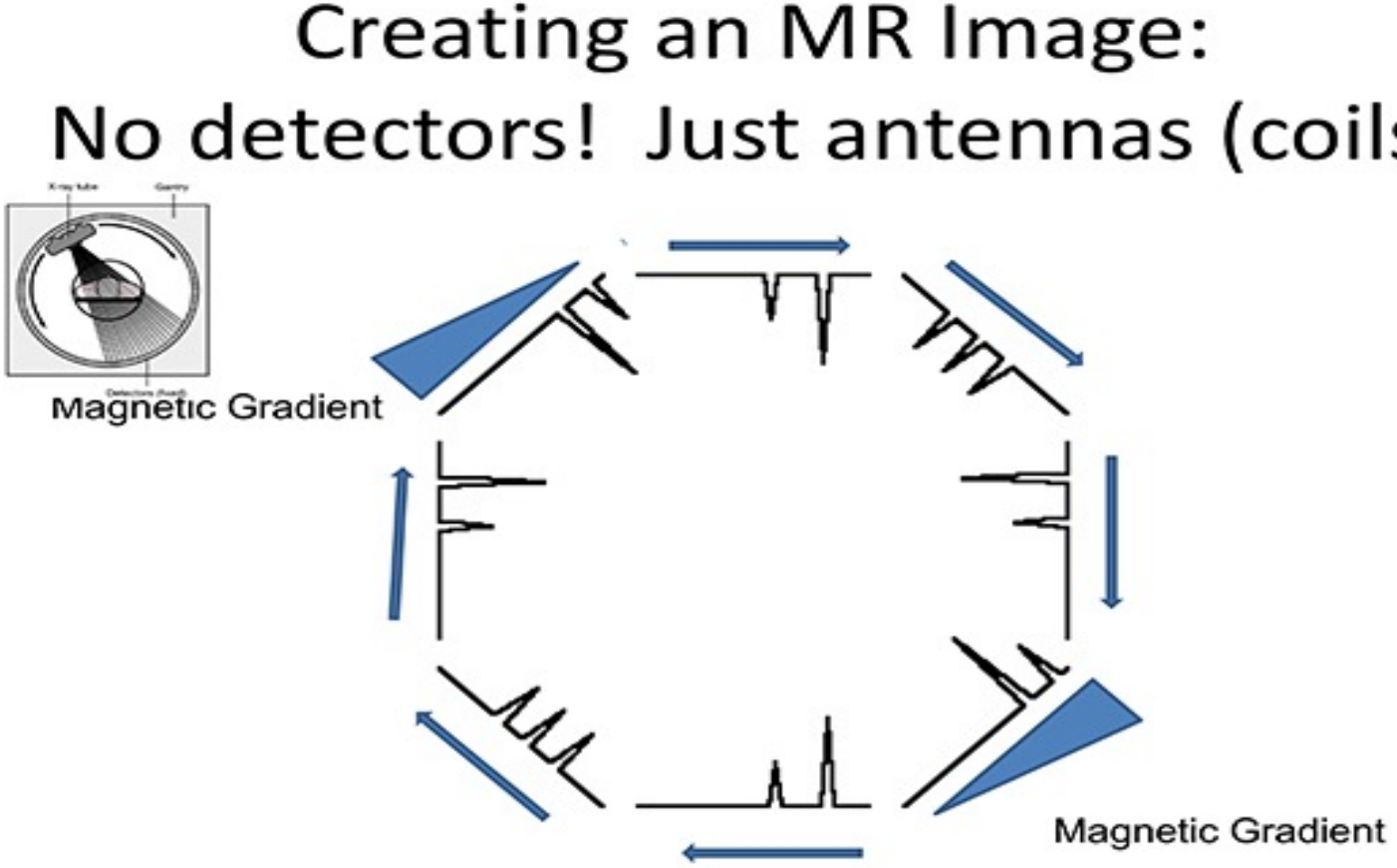
MR Physics



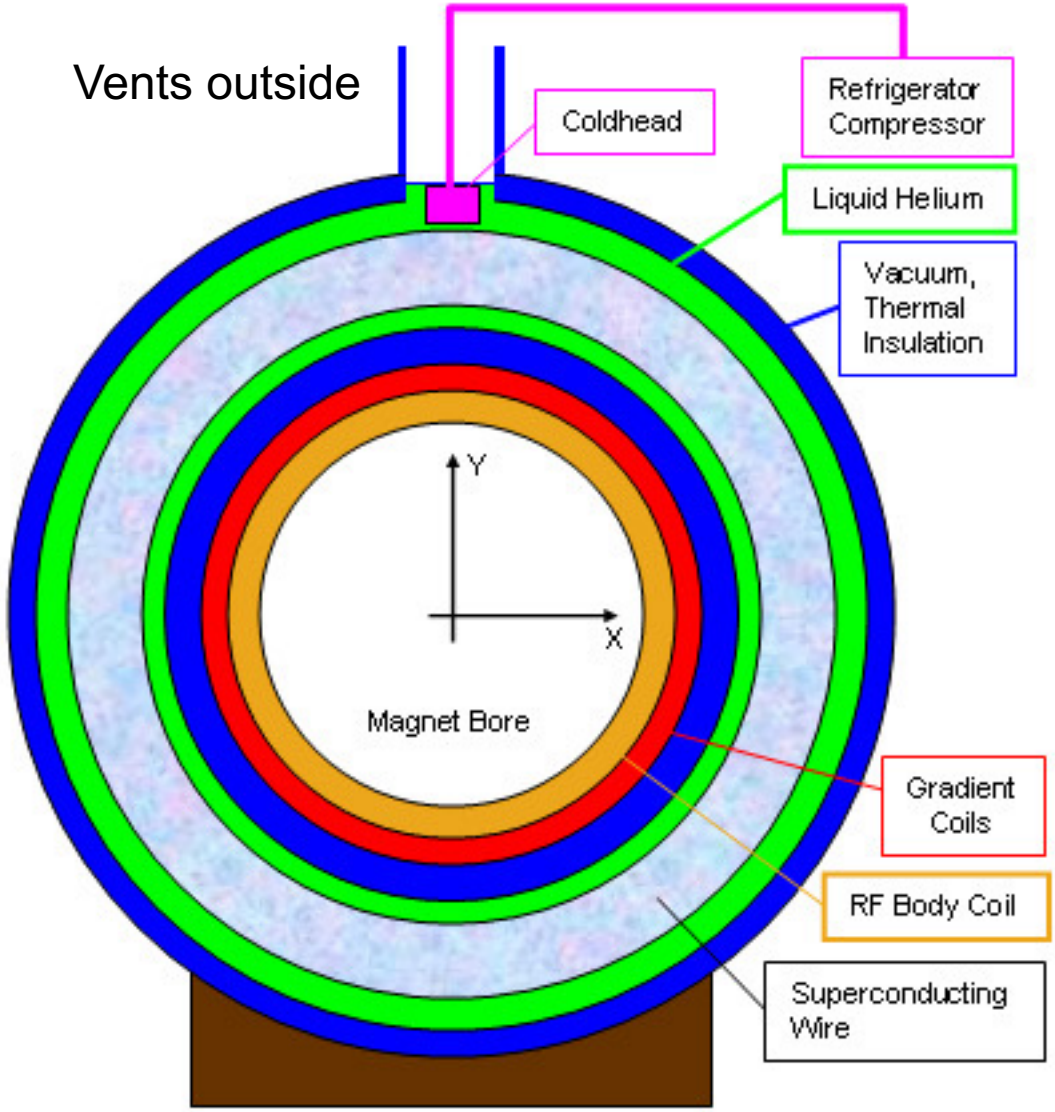
Summary


Z
Y
X
B0
Voxel
a
Net Magnification Vector
90 Degree RF Pulse
Z
Y
X
B0
Net Magnetization Vector
b
TI
TR
180
90
180
90
180
RF
Gz
Signal
TE
TE/2
c

MRI image


Creating an MR Image:
No detectors! Just antennas (coils)
Magnetic Gradient
Magnetic Gradient

Anatomy of an MRI



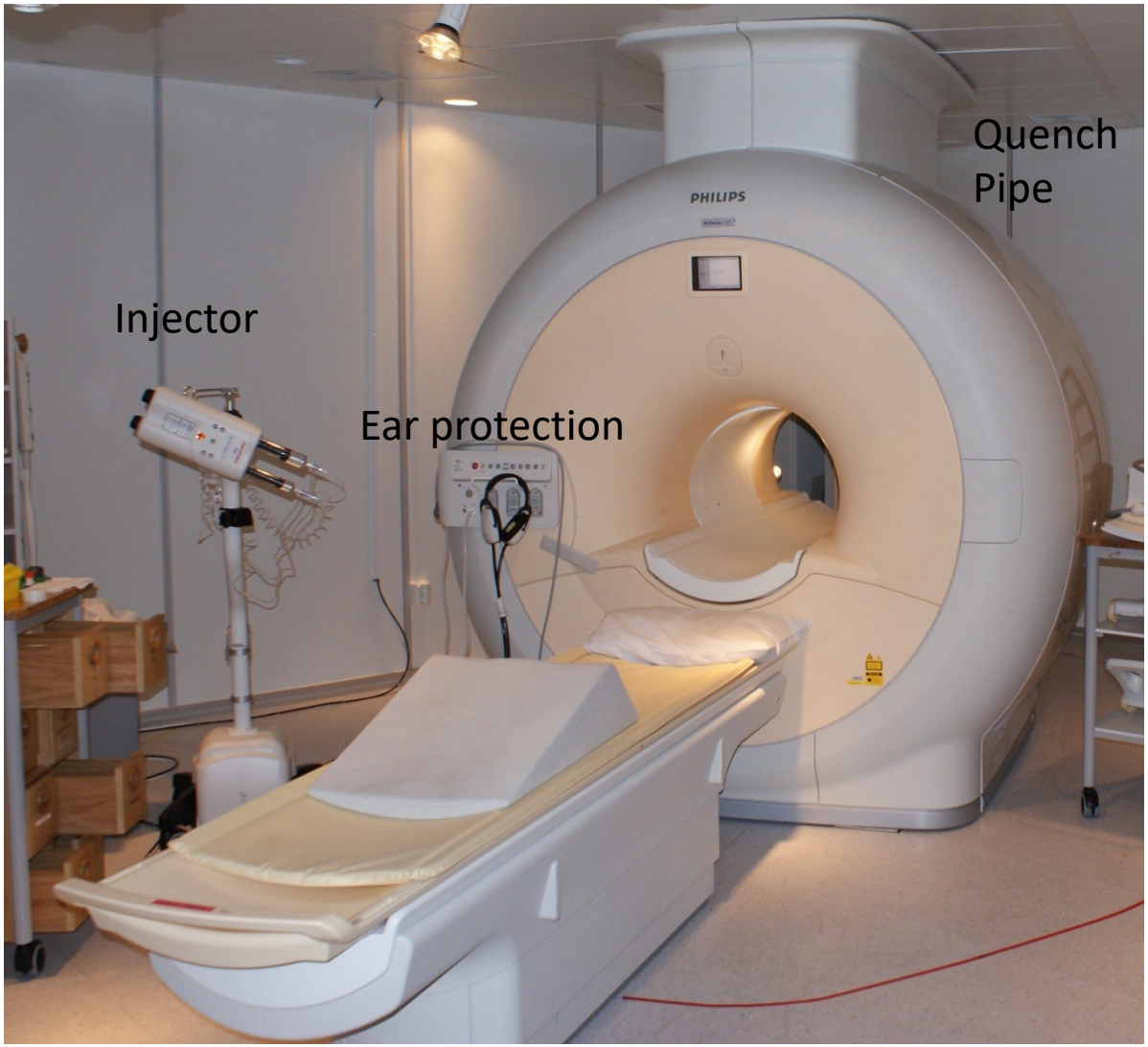
MRI Advantages

- No radiation
- Multiplanar
- Multiple contrast types:
  - T1 weighting, T2 weighting
  - Diffusion weighting
  - Contrast enhanced MRI
  - Spectroscopy

MR Disadvantages

- Slower than CT
- More expensive
- Does not depict calcifications
- Safety issues
  - Metallic objects become projectiles
  - Incompatible with metallic implanted devices
    - Pacemakers
    - Cochlear implants

Safety issues in MRI



MRI safety

MRI SAFETY

- MRI scanners are extremely powerful
- Objects that are attracted by the MRI magnetic field can reach 60 miles per hour.
- A sharp or heavy object can be deadly to anyone standing in its path.
- Metal objects used everyday (scissors, oxygen tanks, infusion pumps, etc) become projectiles
- This can causepotential injury to patients or hospital staff.
- MRI departments are divided into Zones for Safety

MRI safety

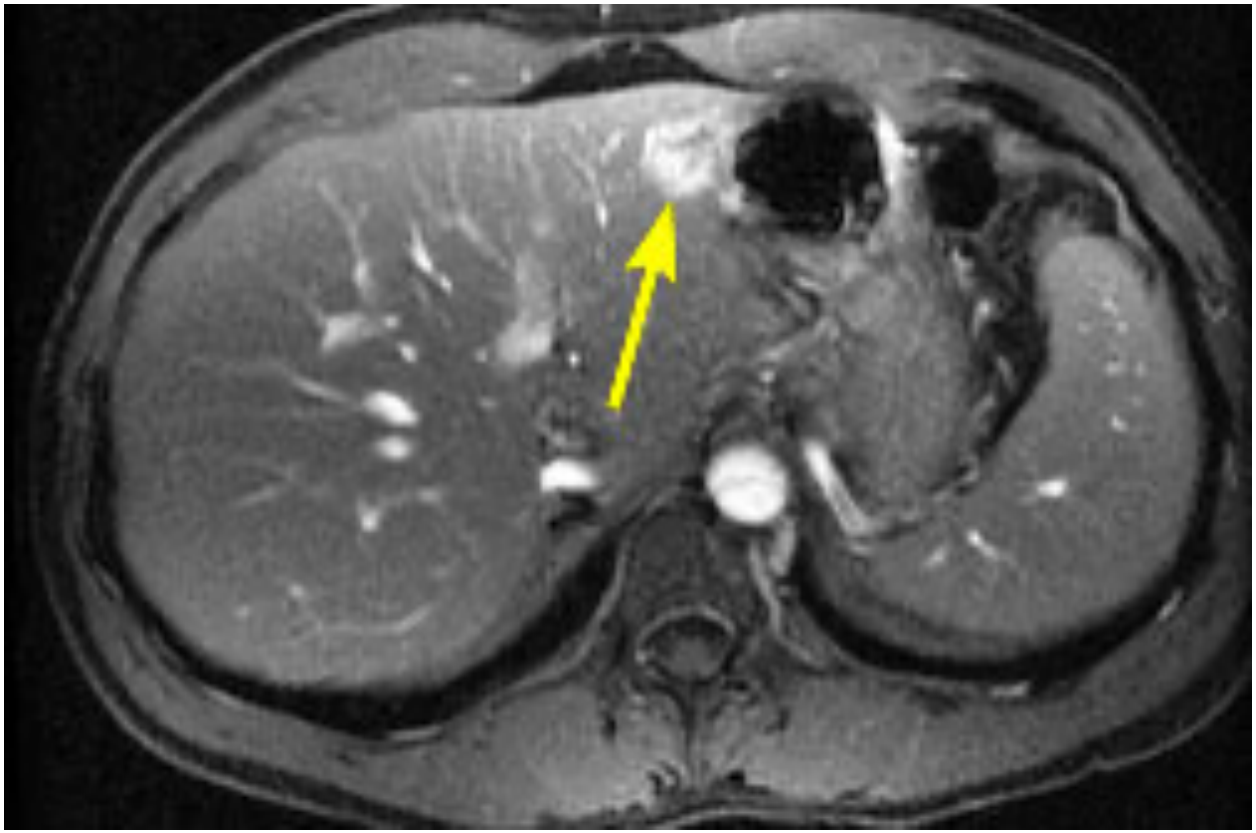
MRI SAFETY

MRI

O2 Tank, “Missile”

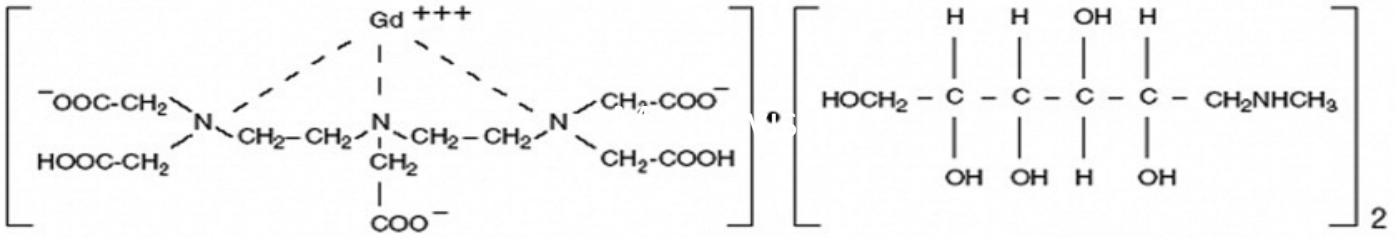
An Oxygen tank can become an Airborne torpedo in an MRI

Value of Contrast Media



Contrast agents

a



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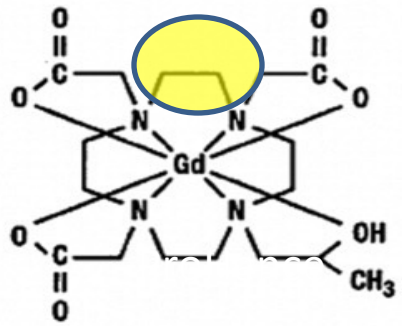
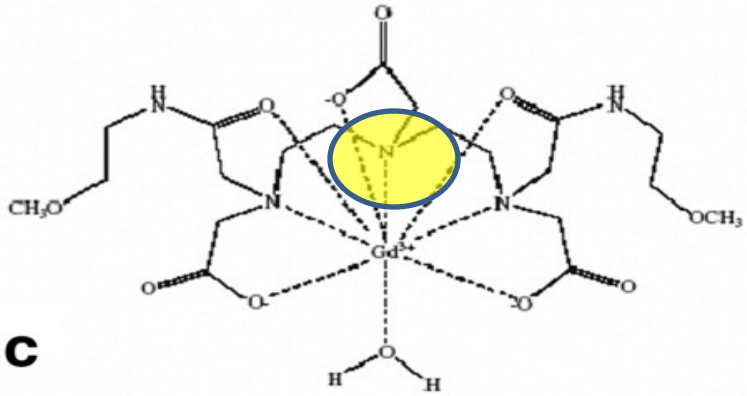


c



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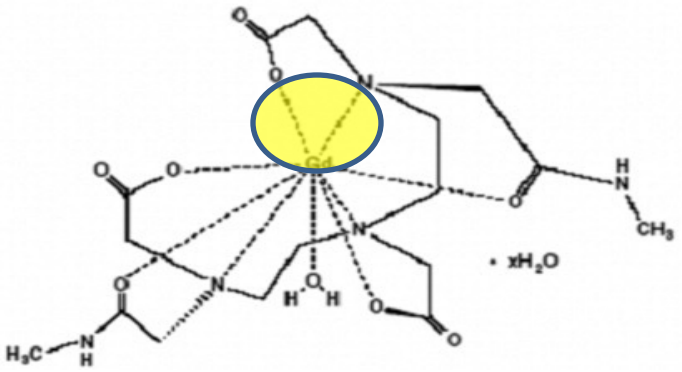
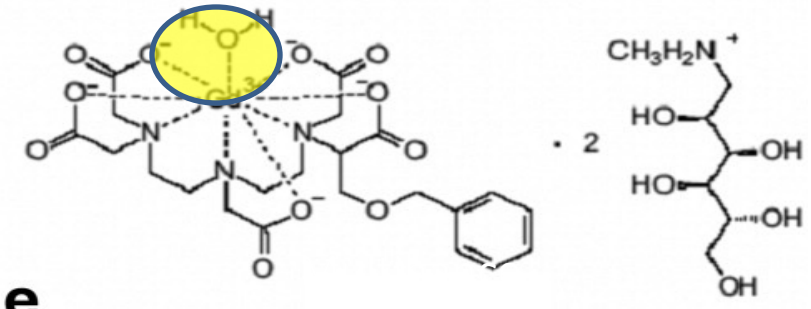


e



Contrast table

Extracellular Gd-CM	Type	Thermodynamic stability constant	Conditional Stability	Amount of excess chelate (mg ml^{-1})	Kinetic stability (dissociation half-life at pH 1.0)
Gadoversetamide, Gd-DTPA-BMEA (OptiMark, Tyco, St. Louis, MO)	Non-ionic linear	16.6	15	28.4	Not available
Gadodiamide, Gd-DTPA-BMA (Omniscan, GE, Waukesha, WI)	Non-ionic linear	16.9	14.9	12	35 s
Gadobutrol, Gd-BT-DO3A (Gadovist, Schering, Berlin, Germany)	Non-ionic cyclic	21.8	Not available	Not available	5 min
Gadoteridol, Gd-HP-DO3A (Prohance, Bracco, Italy)	Non-ionic cyclic	23.8	17.1	0.23	3 h
Gadopentetate Gd-DTPA (Magnavist, Schering, Berlin, Germany)	Ionic linear	22.1	18.1	0.4	10 min
Gadobenate, Gd-BOPTA, (Multihance, Bracco, Italy)	Ionic linear	22.6	18.4	None	Not available
Gadoterate, Gd-DOTA (Dotarem, Guerbet, France)	Ionic cyclic	25.8	18.8	None	>1 month

Fibrosis

Nephrogenic systemic Fibrosis

Patient with very poor renal function received multiple linear Gd injections for MRI.

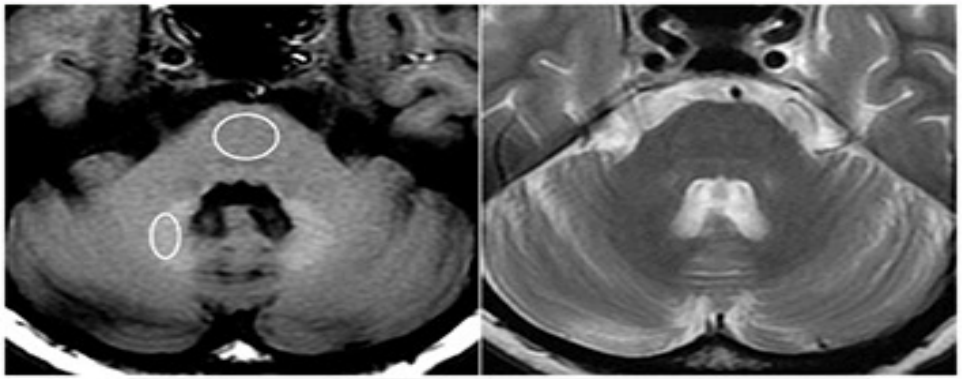
AJR 188 Feb 2007

Mechanism

- Gadolinium is highly toxic
- Patients with normal renal function excrete Gd-chelates within 24-48h
- Patients with abnormal renal function may take weeks to excrete the agent
- Dissociation of Gd from the chelate could deposit in soft tissues (documented)
  - Hugh et al. Tissue Gd conc .14-24 ng/mL
- Fibrosis is an inflammatory response to toxic Gd ion.

Residual gadolinium

Residual Gadolinium!



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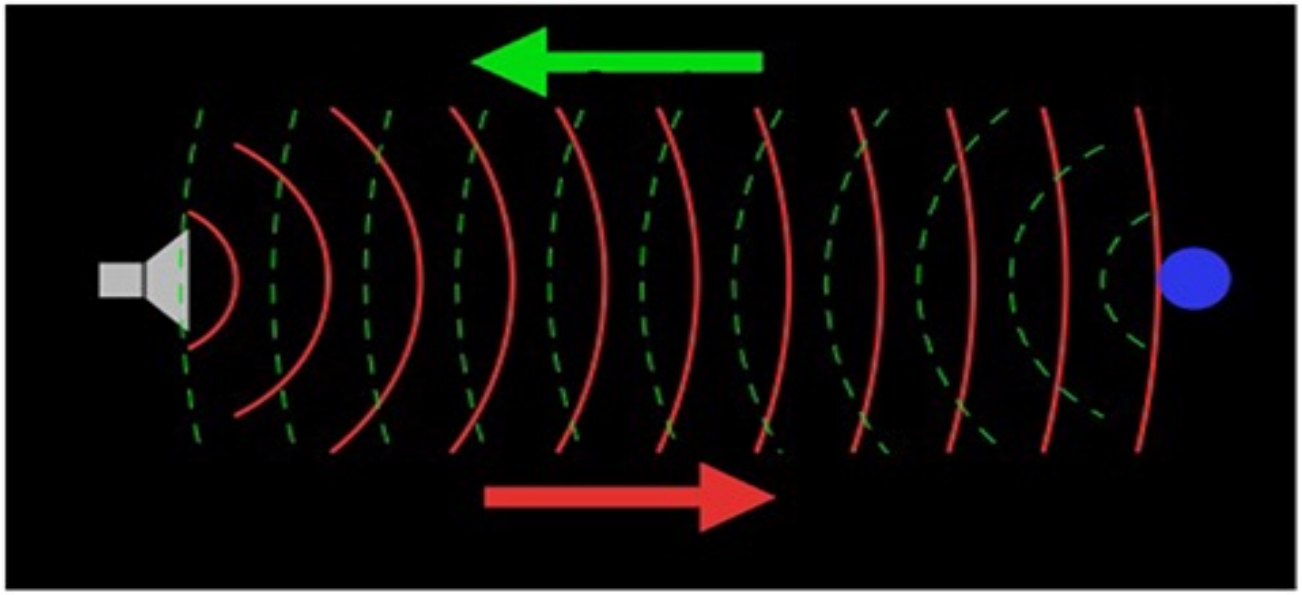
Gadoterate, Gd-DOTA (Dotarem, Guerbet, France)	Ionic cyclic	25.8	18.8	None	>1 month

Ultrasound


11.08.2004
RAB4-8-D/D8
MI 1.1
Dr. Herodes ecofetale.com
TIS 0.1
02.02.2012
12:41:04
CRL
CRL 4.81cm
GA 12w6d 71.6%

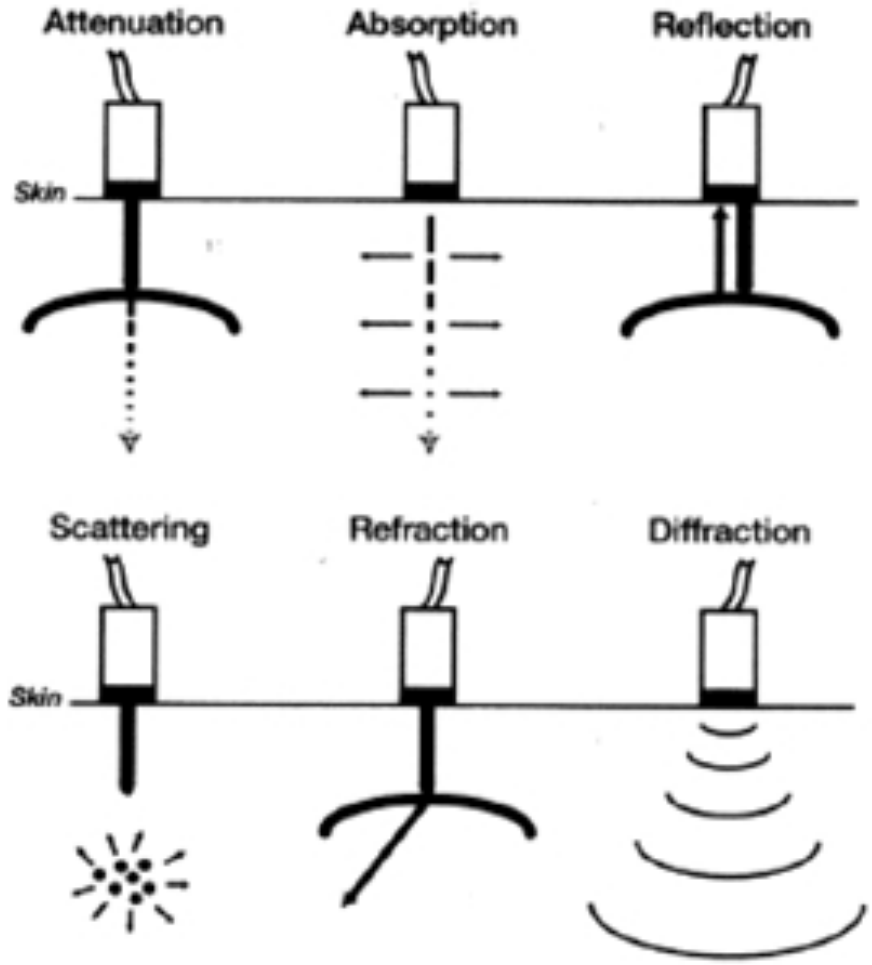
Ultrasound basics

US basics



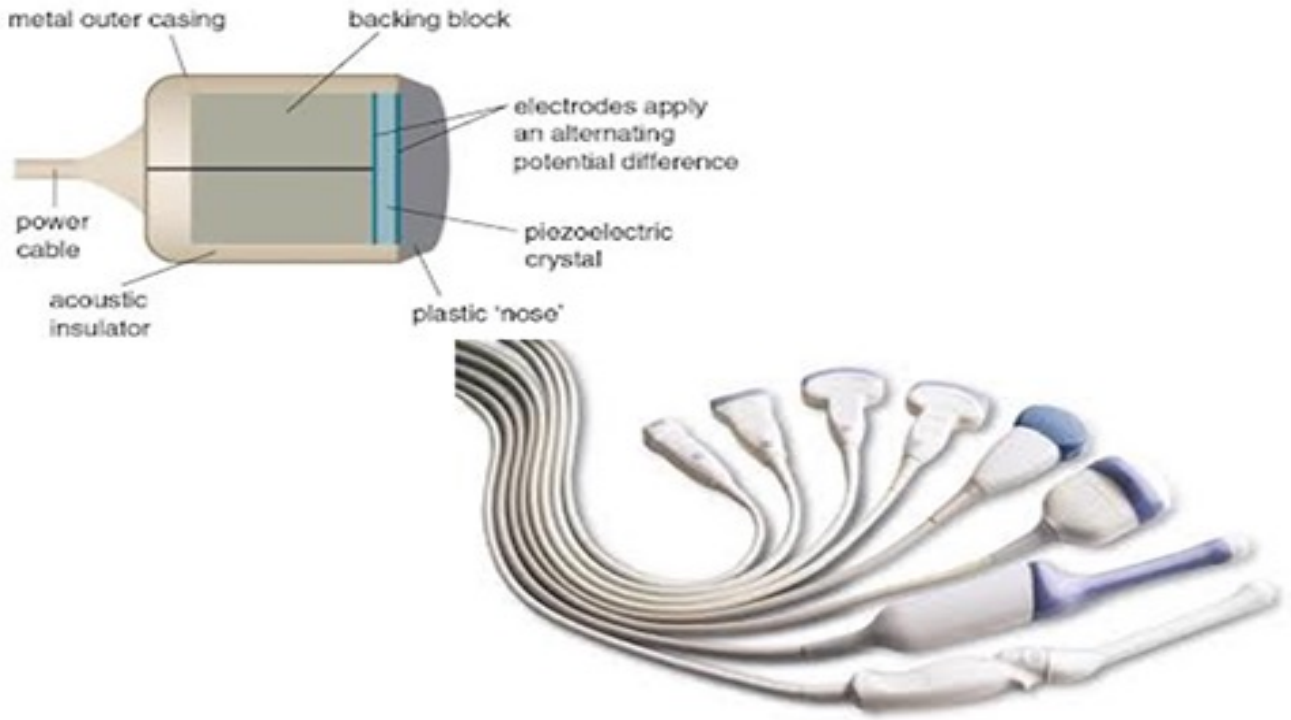
Imaging dependent on the speed of sound
In tissue

Fate of sound waves in body

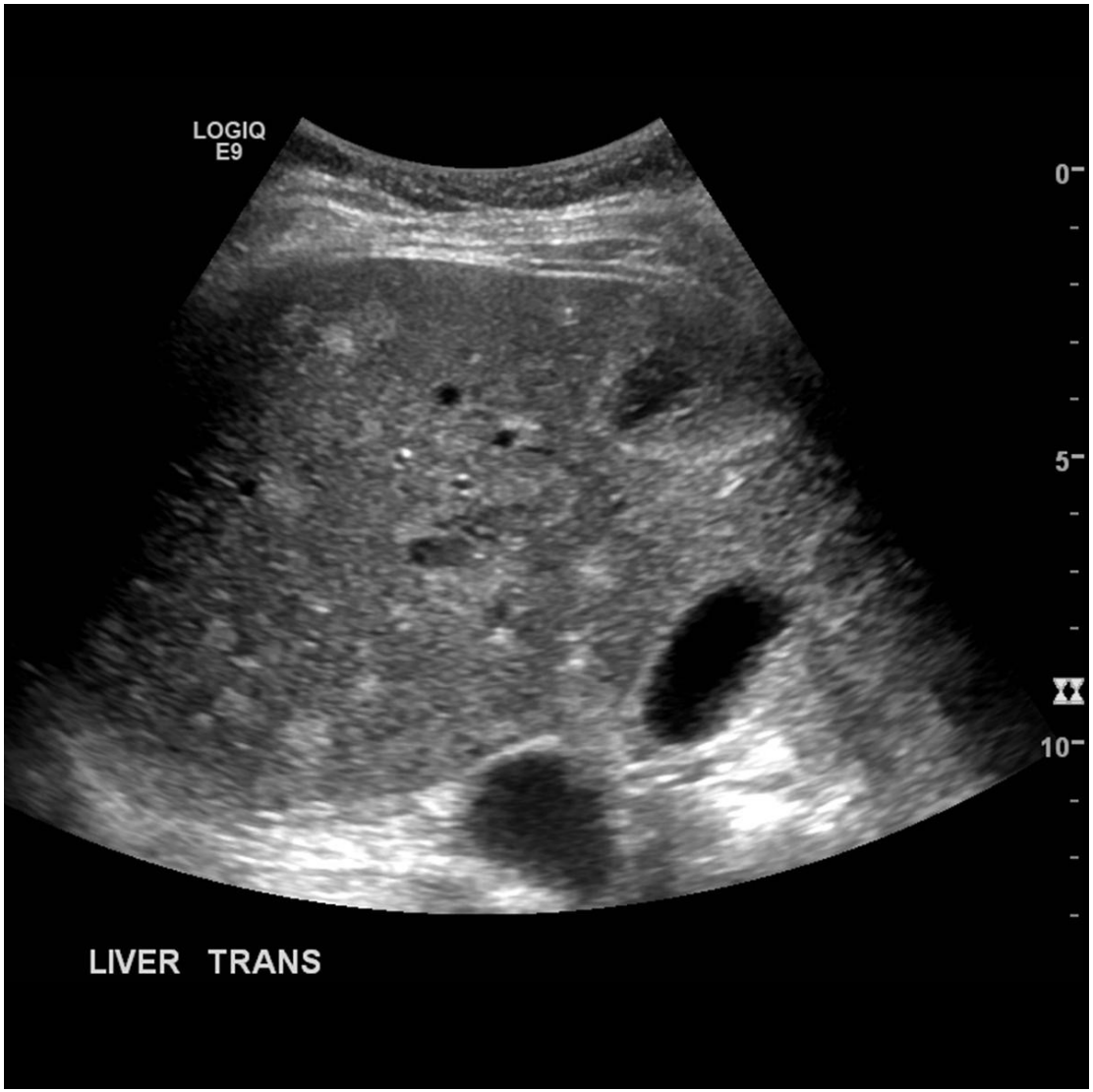


Ultrasound probes

US Probes



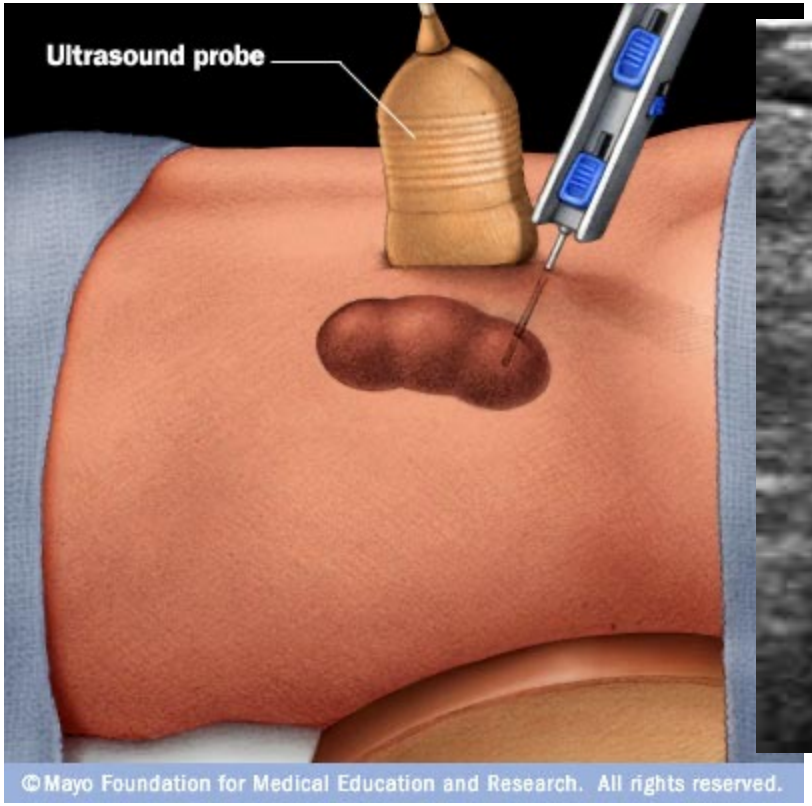
Liver metastases

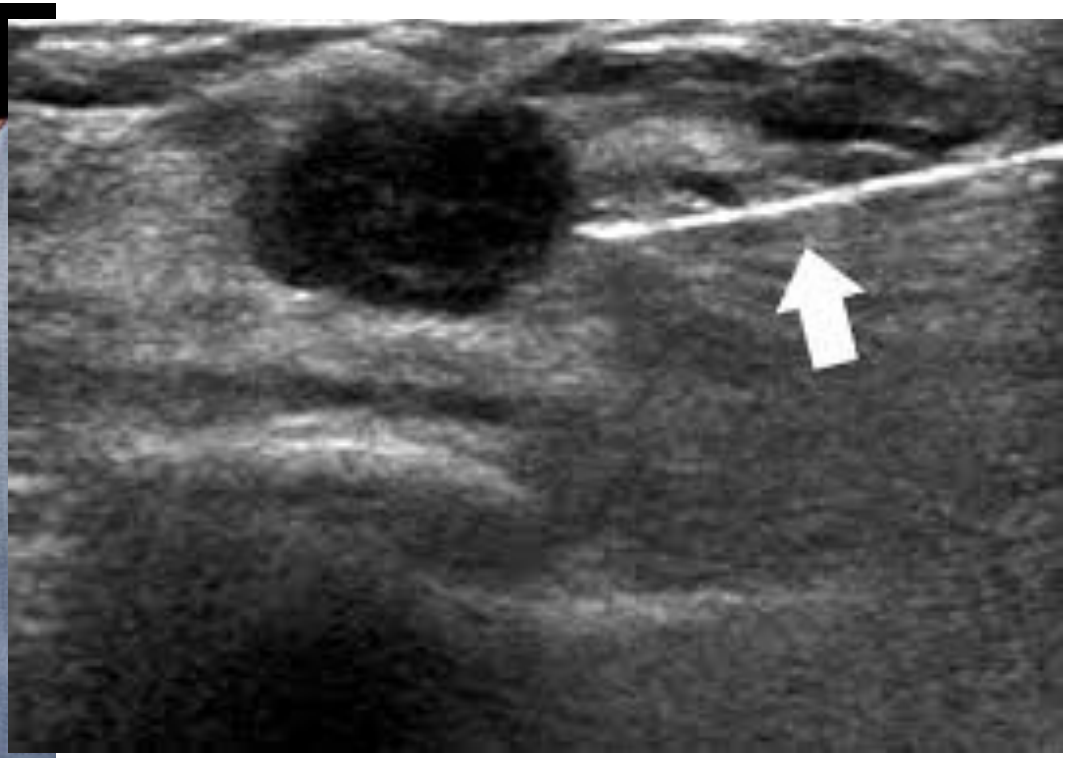


Ultrasound devices

Evolution of US devices

US guided biopsy-real time





US advantages

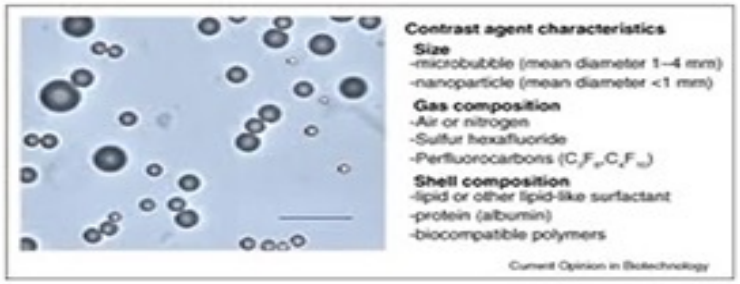
- No radiation
- Real time
- Inexpensive
- Quick, little prep
- No injection

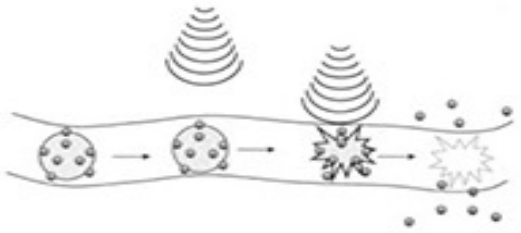
US disadvantages

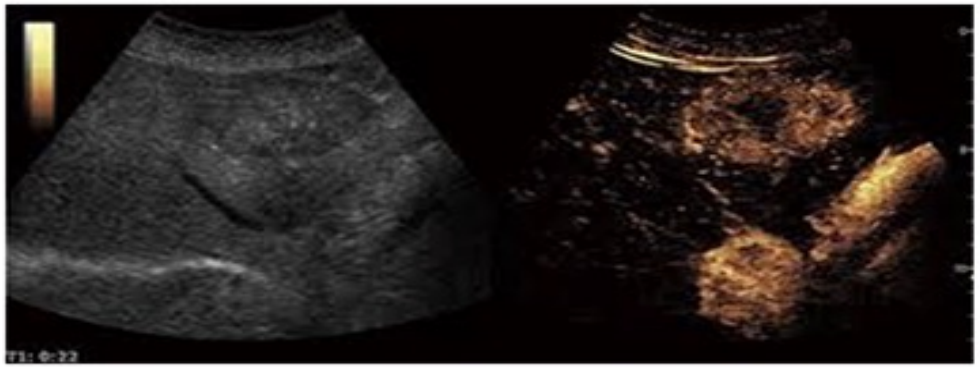
- Operator dependent
- What you see is all there is
- Difficult to quantify
- Limited access (lungs, brain, bone etc.)

Microbubble contrast

US Microbubble contrast



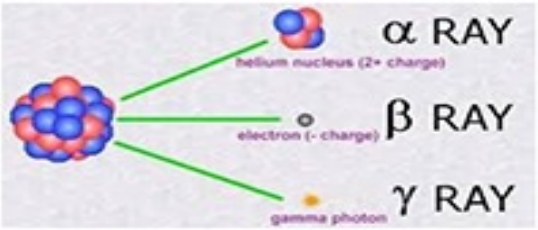




SPECT

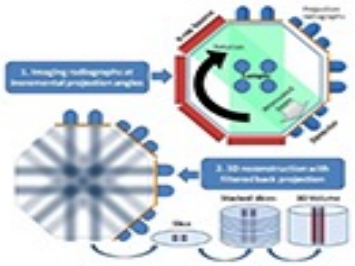
Single Photon Emission Computed Tomography-SPECT

- Single Photon Emission



+

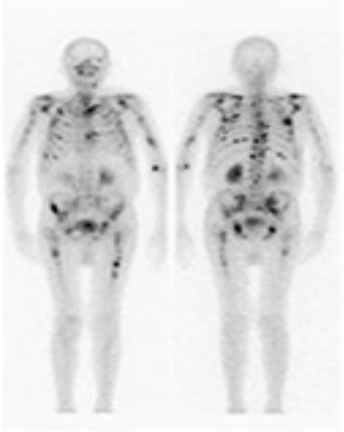
- Computed Tomography



SPECT imaging

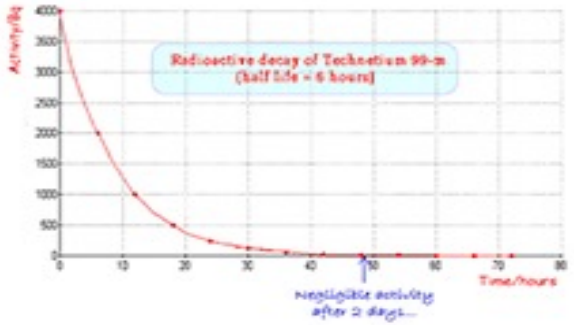
SPECT Imaging

- Requires conjugation of a radioactive isotope to a compound of interest which is injected into the patient:

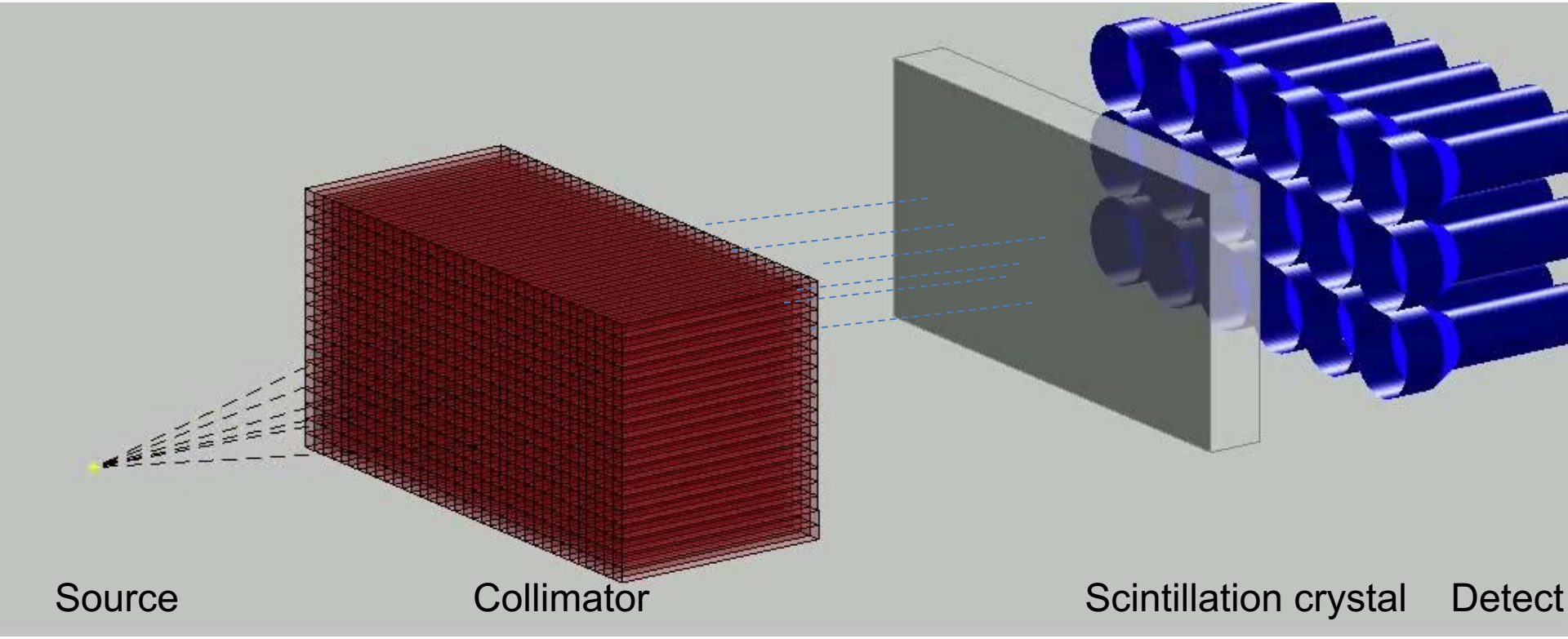


The bone scan:

^{99m}Technetium-methyl diphosphonate

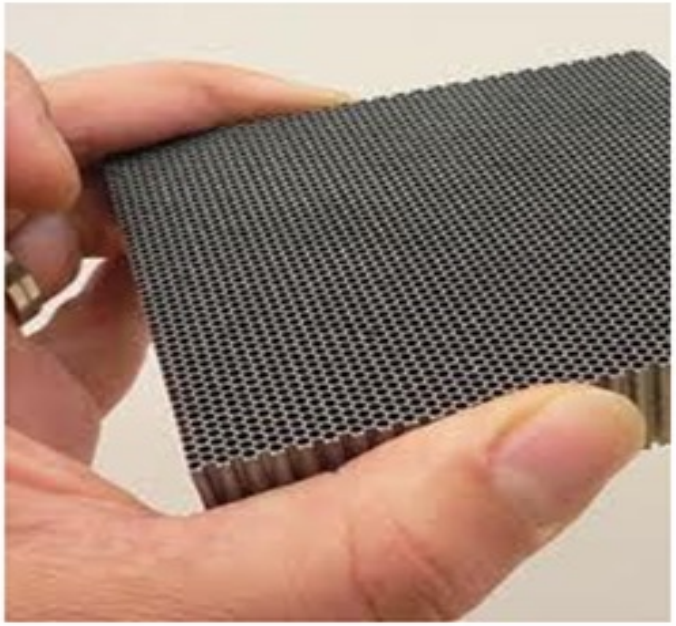


SPECT detectors



Collimation

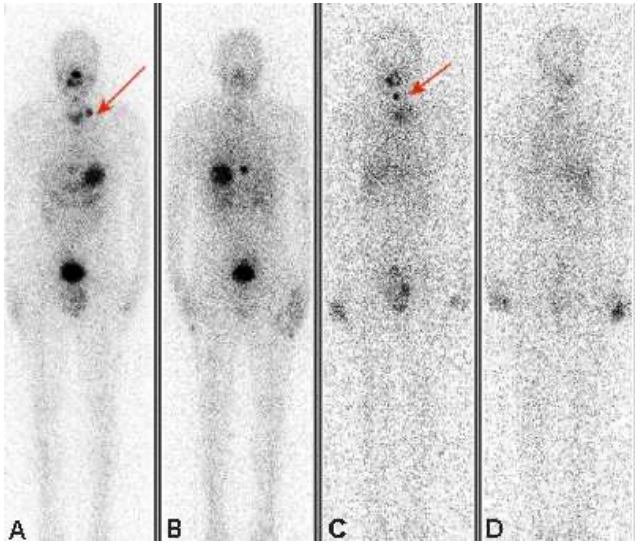
Collimation cont'd



Collimation reduces the sensitivity and resolution of SPECT by rejecting the majority of events

SPECT agents for cancer

- ^{99m}Tc MDP Bone Scan
- ^{99m}Tc Pertechnetate (thyroid, salivary gland)
- ^{201}Thallium Chloride (parathyroid)
- ^{111}Indium oxine (WBC labelling)
- ^{131}Iodine (thyroid)



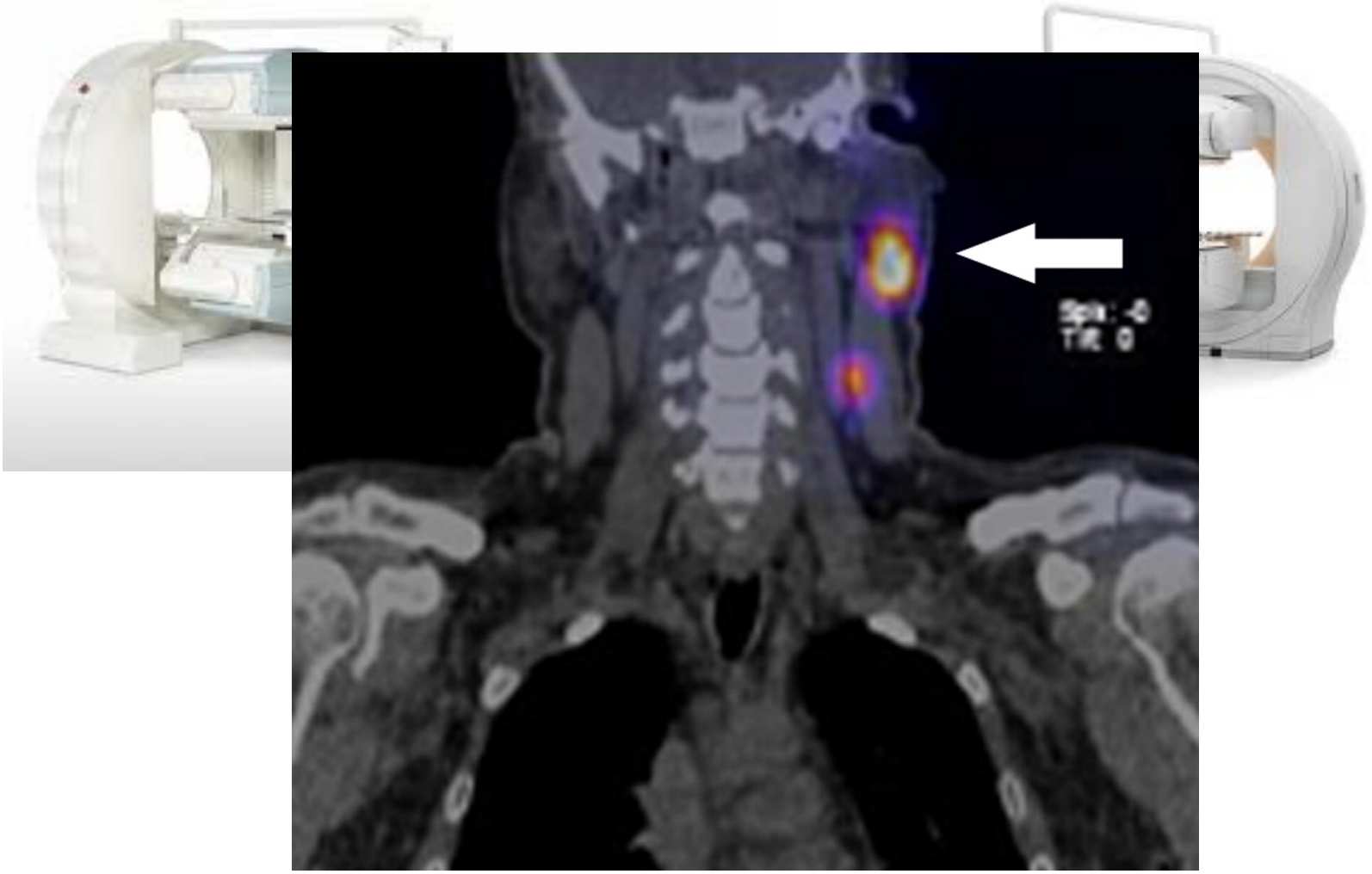
SPECT

SPECT Advantages/Disadvantages

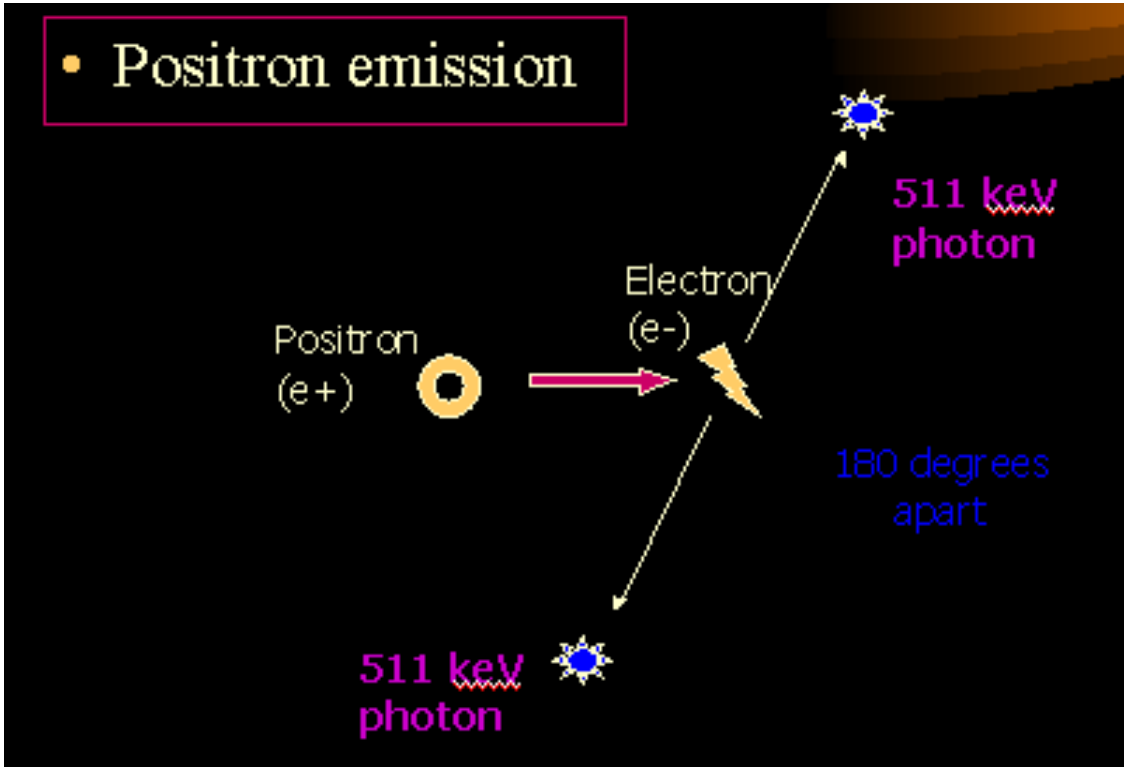
- Relatively inexpensive
- Broad experience

- Disadvantages
  - Radiation exposure
  - Preparation of imaging agent
  - Nuclear Regulatory
  - Scanning is slow, low resolution

Hybrid Imaging



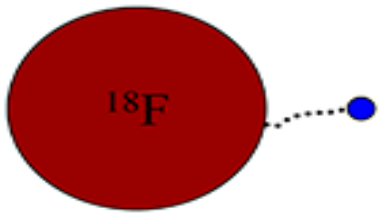
Positron Emission Tomography



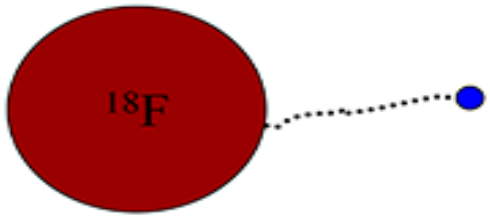
PET1

Positron Emission Tomography

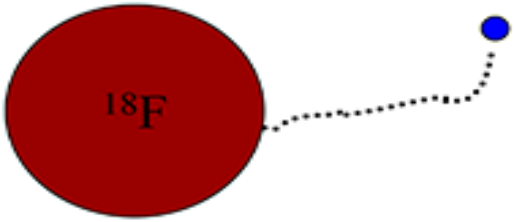
PET2



PET3

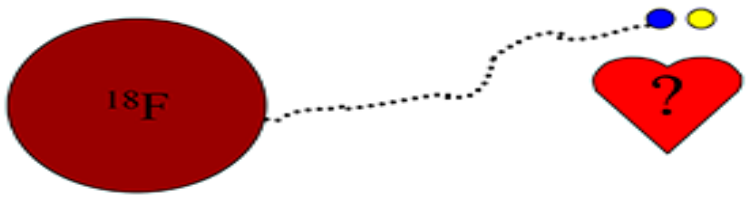


PET4

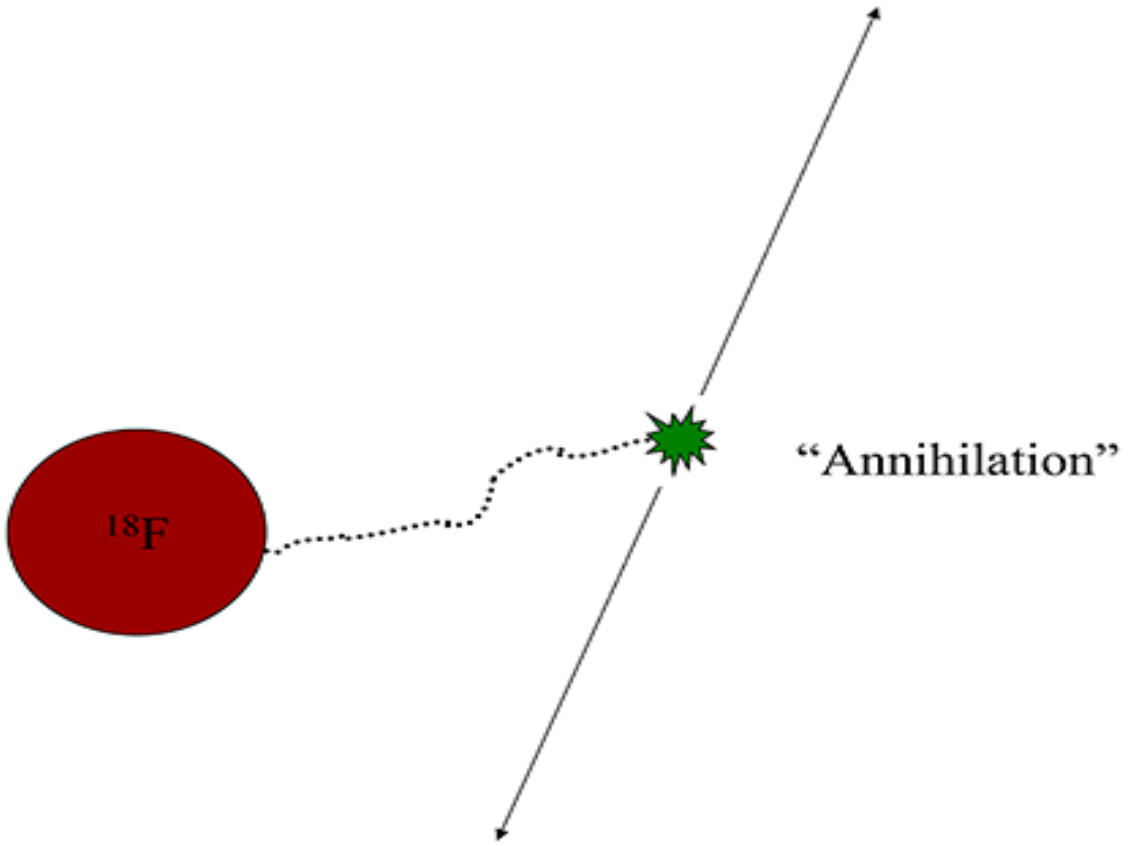


PET5

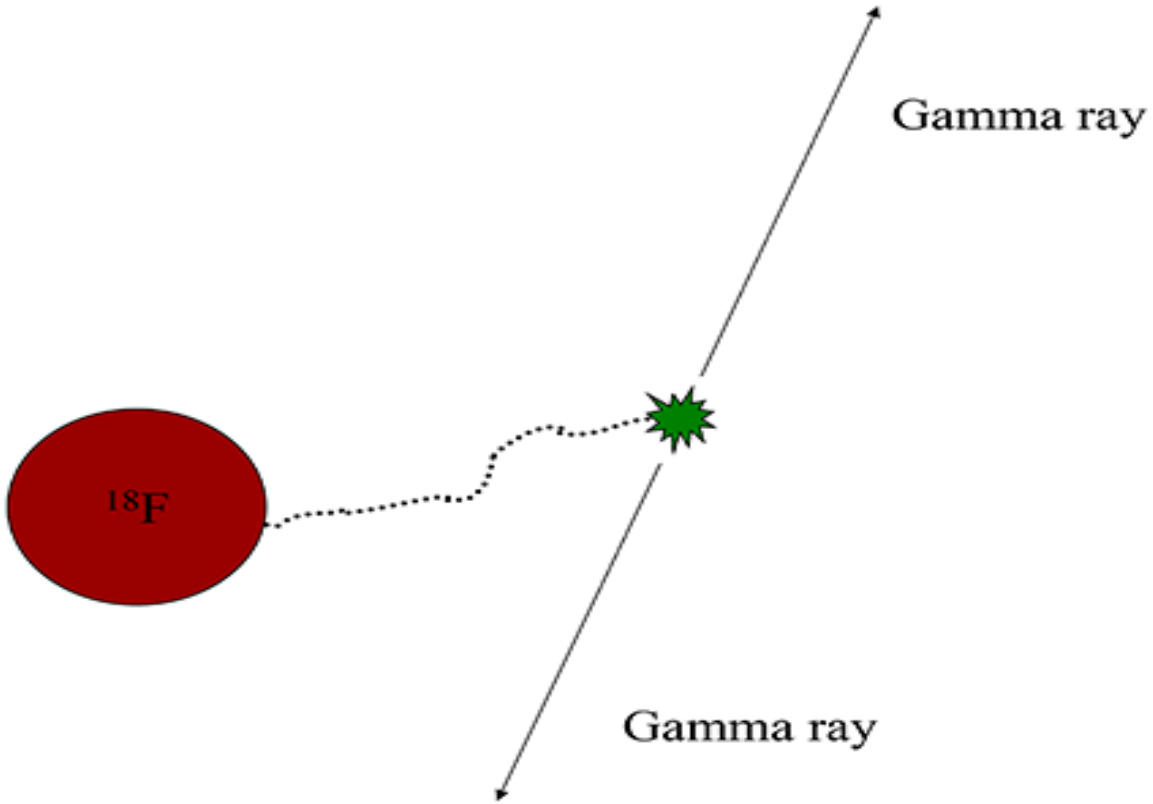
PET6



PET7

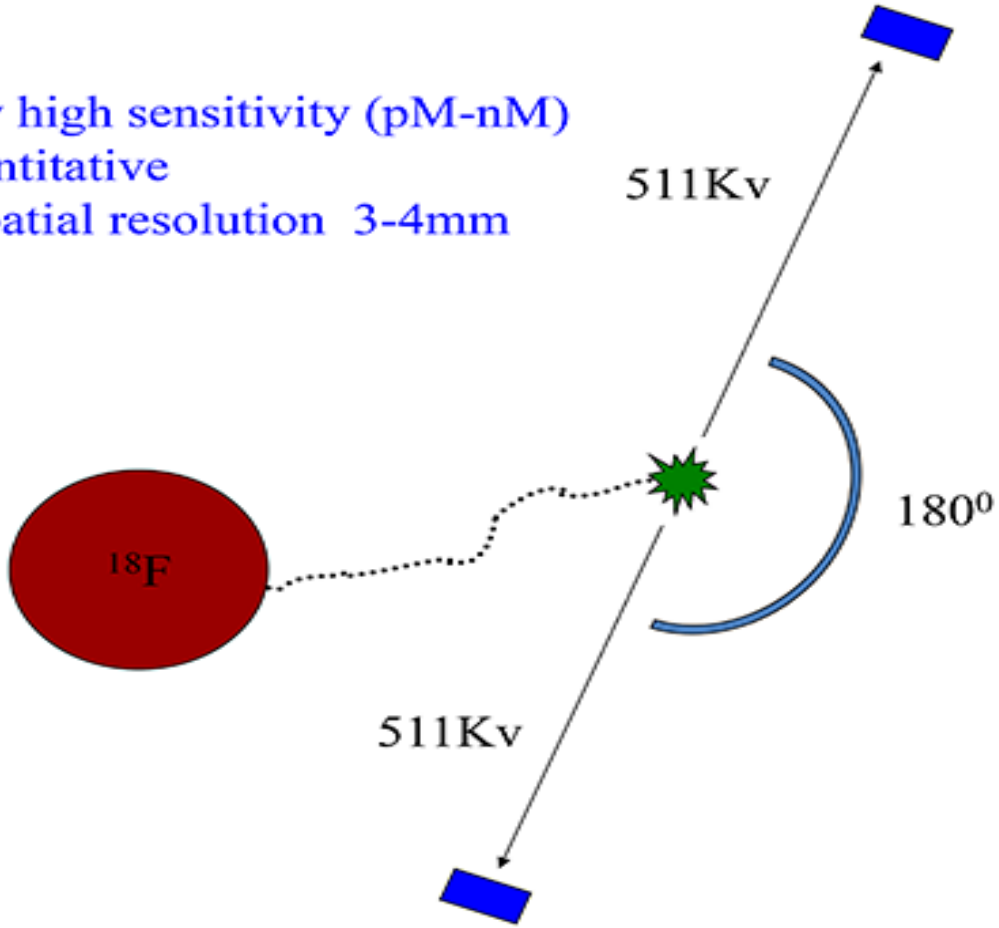


PET8



PET9

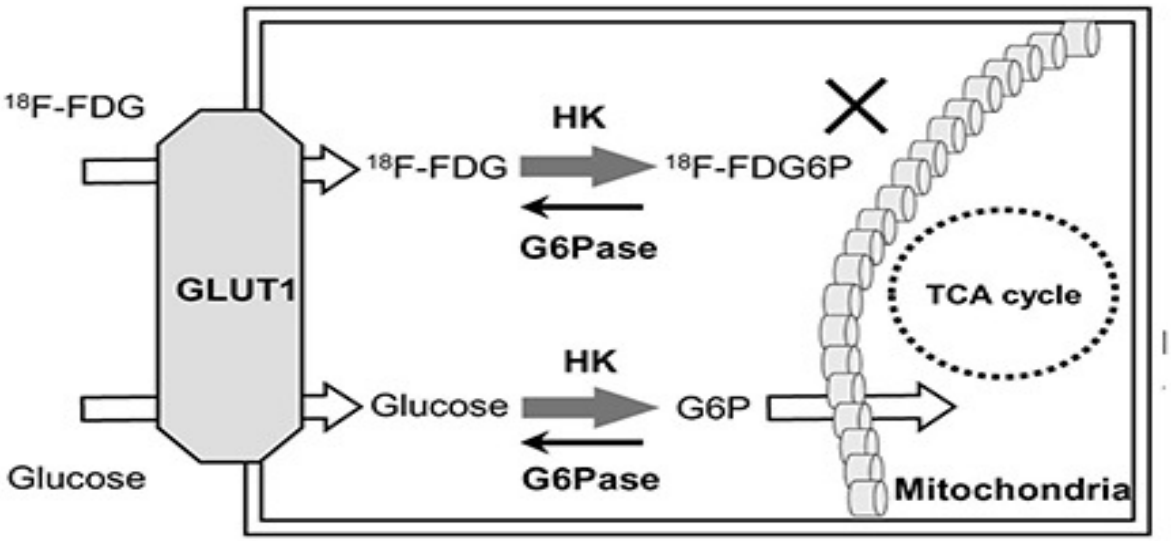
Very high sensitivity (pM-nM)
Quantitative
± Spatial resolution 3-4mm



F-18 Deoxyglucose

Otto Warburg

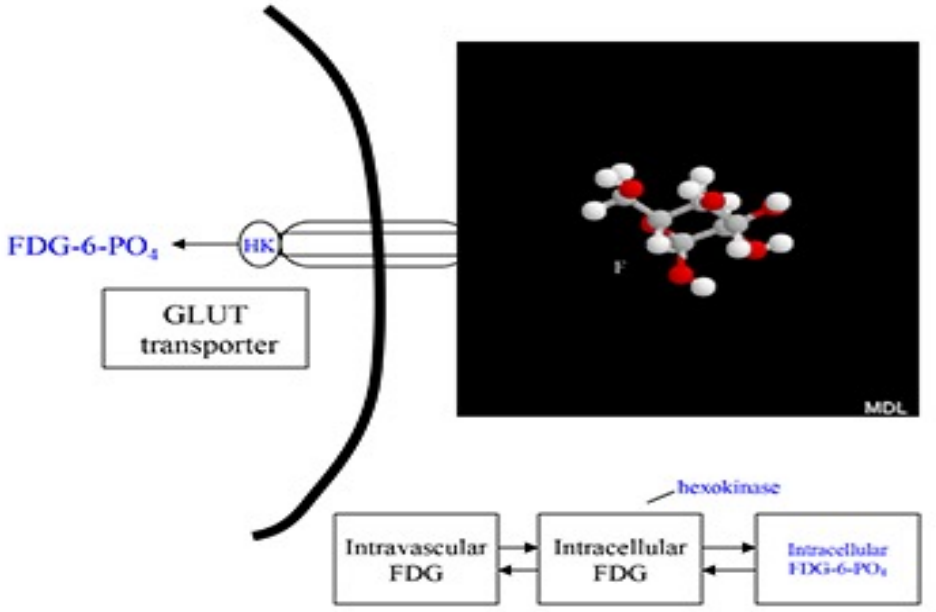
Lou Sokoloff



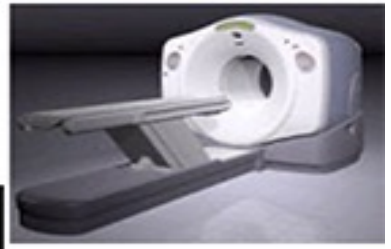
PET imaging

^{18}FDG PET Imaging

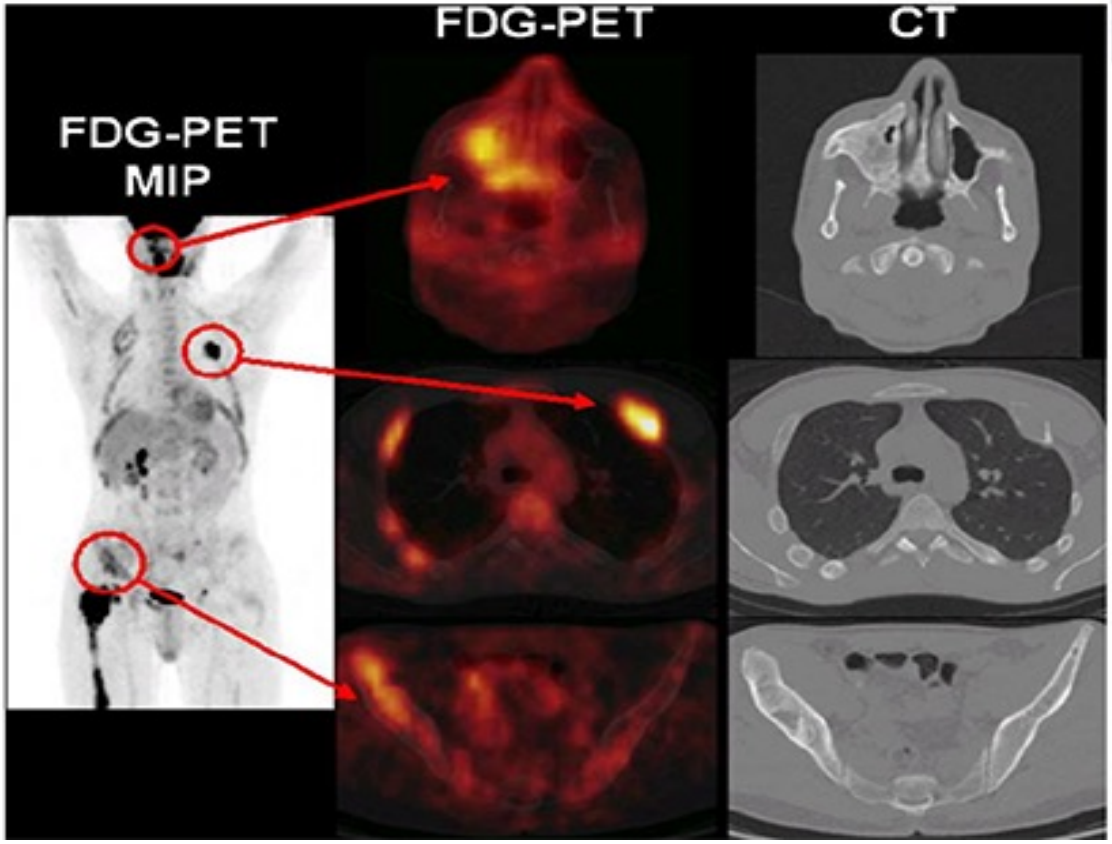
E PET MIP



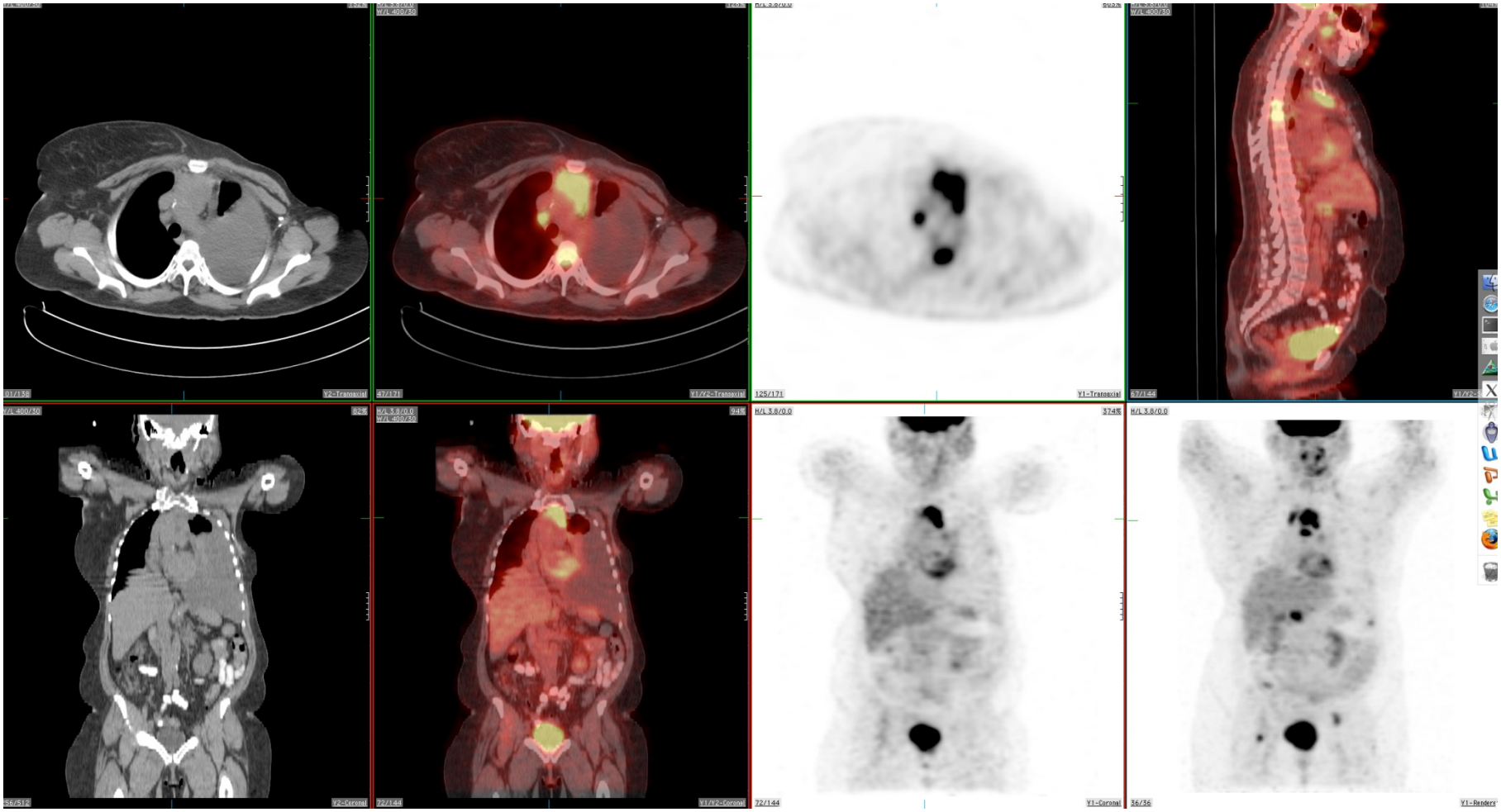
PET scanners



PET-CT scanners



Mediastinal and spine metastases (breast)



Metastatic Breast Cancer

Notable PET Agents

- Sodium Fluoride: Bone target
- Fluorothymidine: Cellular Proliferation
- Fluoroestadiol: Estrogen receptor
- Fluorocholine: Membrane Turnover
- Fluoromiso: Hypoxia
- Florbetaben: Amyloid (Alzheimers)
- Zirconium Herceptin: labeled antibody
- Zirconium Oxine: Cell labeling

PET imaging

Positron emission tomography (PET) has the advantages of:

- High energy photon imaging
- High sensitivity moderate specificity
- The ability to correct for attenuation
- No need for collimation
- Resolution is still limited

Presentation

Summary of Cancer Imaging

Presentation	Resolution	Sensitivity	Cost (low-hi)
CT	CT	PET	US
MRI	MRI	SPECT	CT
US	US	US (microbubble)	SPECT
SPECT	PET	MRI	MRI
PET	SPECT	CT	PET

Resolution

Summary of Cancer Imaging

Presentation	Resolution	Sensitivity	Cost (low-hi)
CT	CT	PET	US
MRI	MRI	SPECT	CT
US	US	US (microbubble)	SPECT
SPECT	PET	MRI	MRI
PET	SPECT	CT	PET

Sensitivity

Summary of Cancer Imaging

Presentation	Resolution	Sensitivity	Cost (low-hi)
CT	CT	PET	US
MRI	MRI	SPECT	CT
US	US	US (microbubble)	SPECT
SPECT	PET	MRI	MRI
PET	SPECT	CT	PET

Cost

Summary of Cancer Imaging

Presentation	Resolution	Sensitivity	Cost (low-hi)
CT	CT	PET	US
MRI	MRI	SPECT	CT
US	US	US (microbubble)	SPECT
SPECT	PET	MRI	MRI
PET	SPECT	CT	PET

General Guidelines

- Overall “workhorse” for oncology: CT
- Specialty cancers: brain, liver, prostate: MRI
- Problem solving (e.g cyst vs. solid): US
- Bone mets: SPECT
- Metabolic activity: PET

Imaging of Cancer:

http://mip.nci.nih.gov
pchoyke@nih.gov