Imaging of Cancer

Imaging of Cancer:

Subtitle: What actually happens in a Radiology Department?

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Molecular Imaging Program, NCI

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

The Main Imaging Devices

Quiz: Name that Scanner

CT

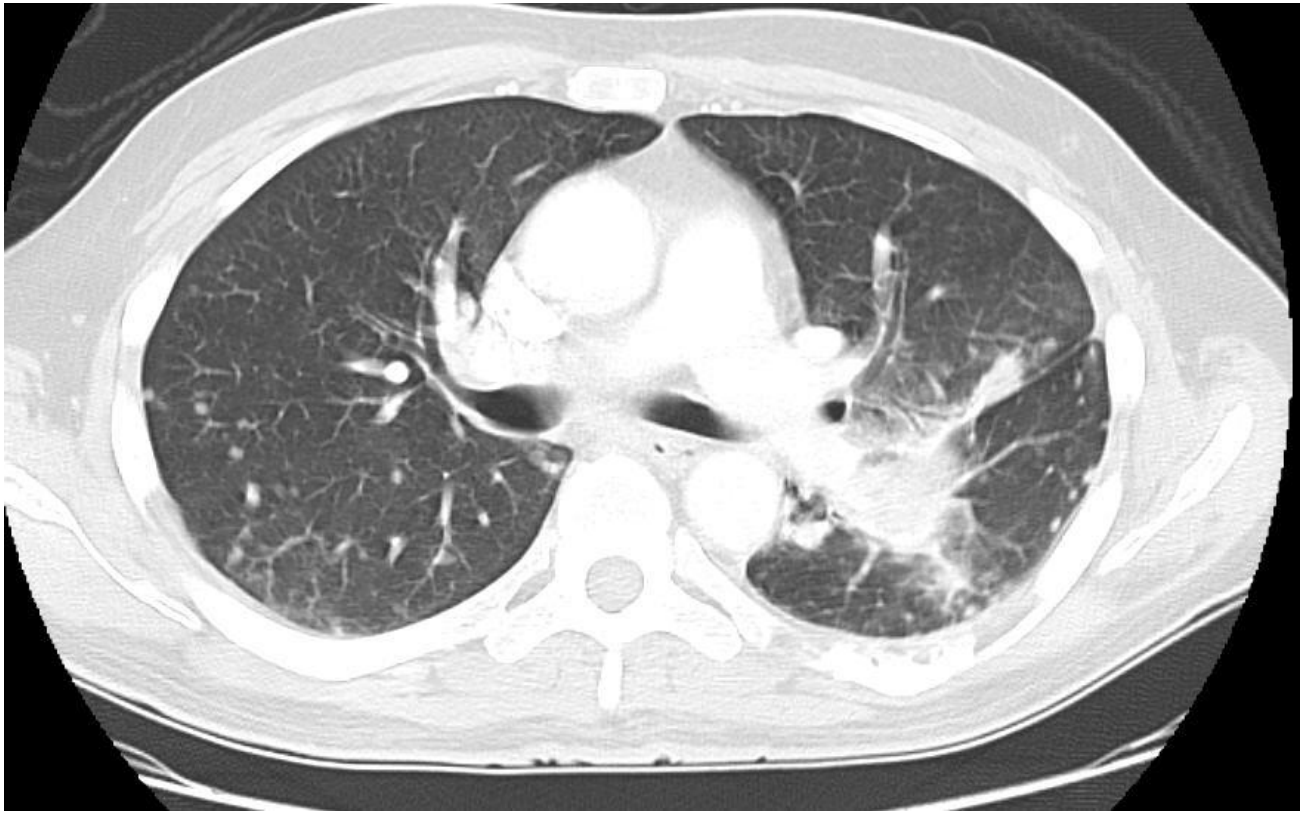
MRI

US

SPECT

PET

Computed Tomography



Advantages of CT

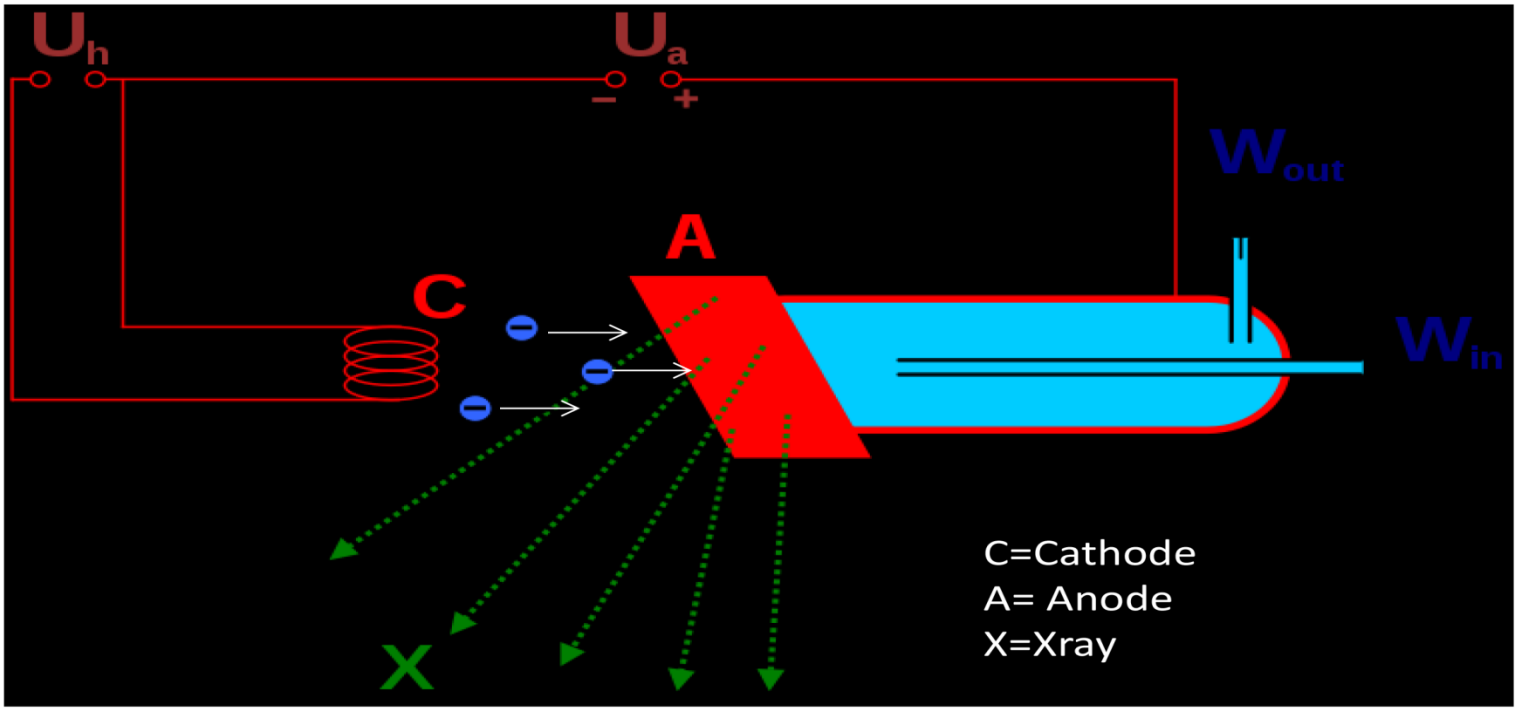
- Widely available
- Minimal prep (NPO, drink contrast)
- Very rapid (2-3 seconds neck to pelvis)
- High resolution
- Relatively inexpensive

Disadvantages

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

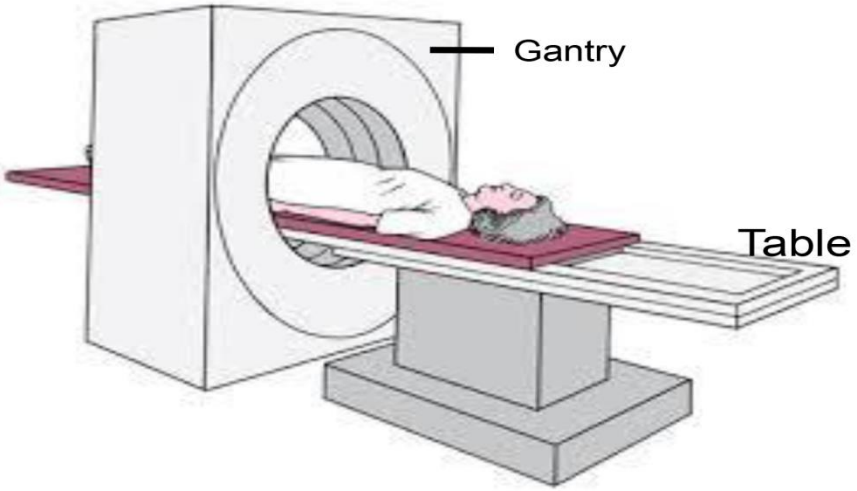
X-ray production

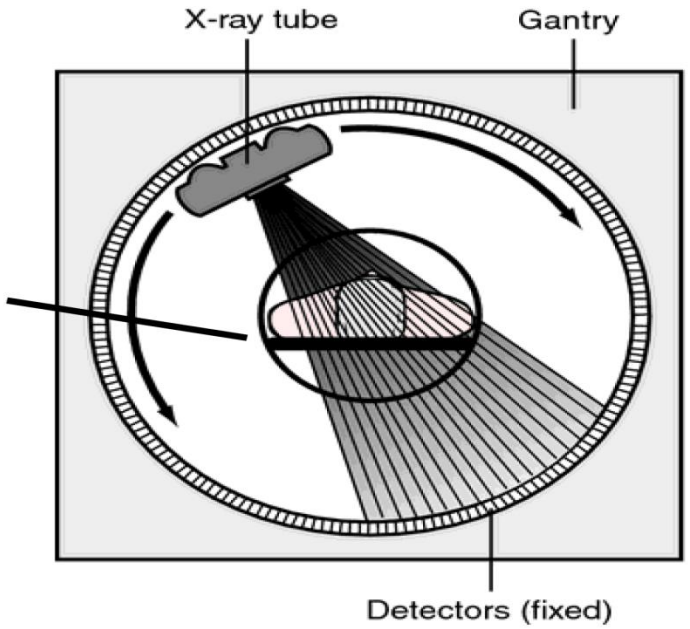
X-ray production: cathode ray tube



Basics of CT

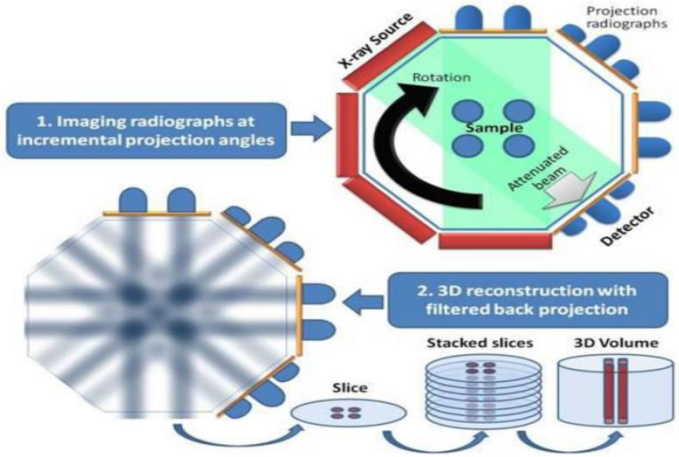
Basics of CT





CT projection

Filtered Back Projection



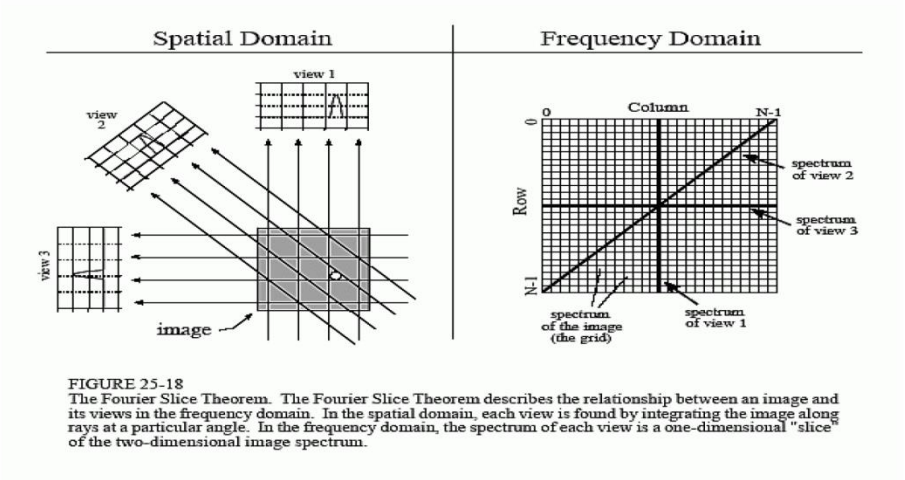
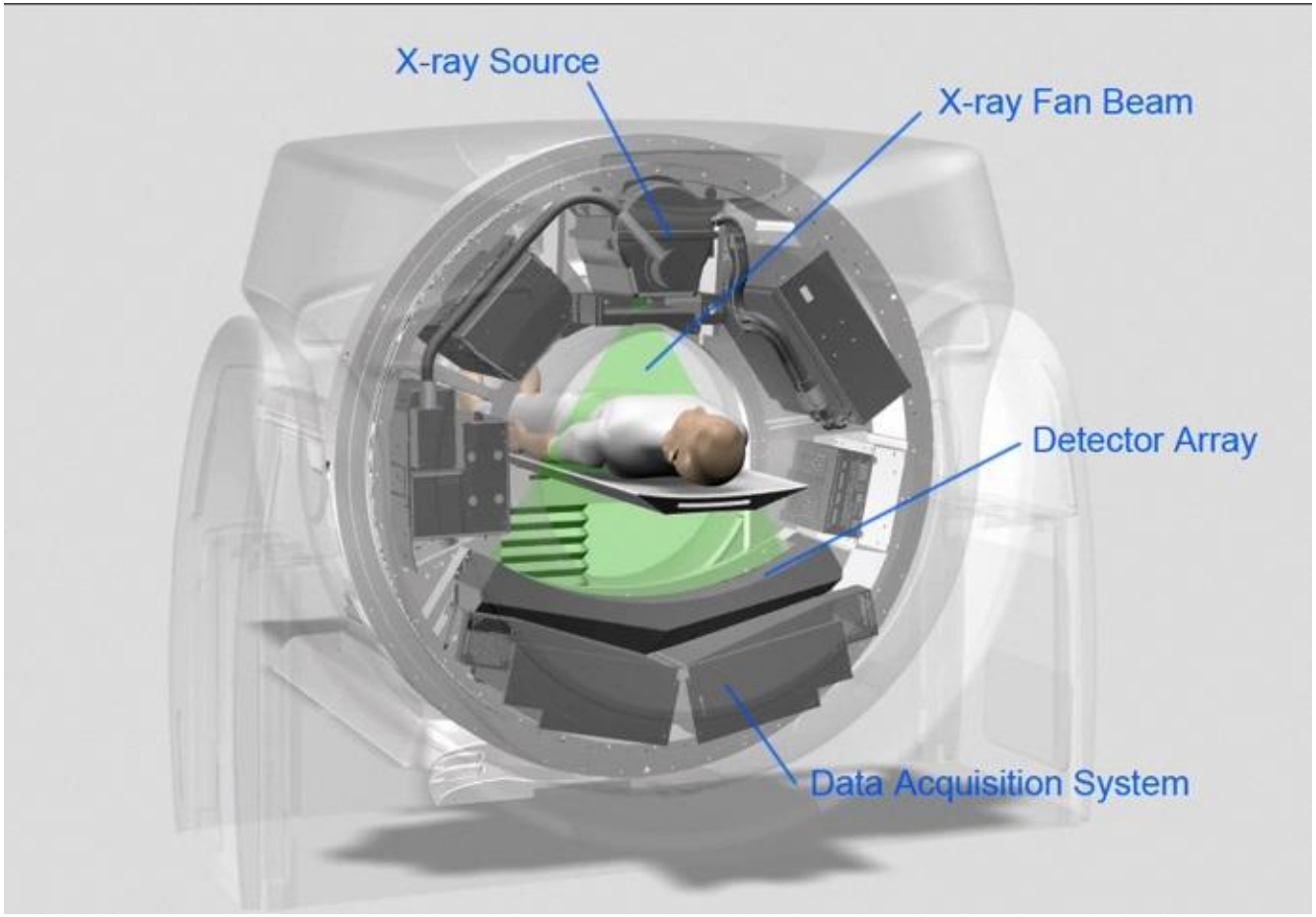
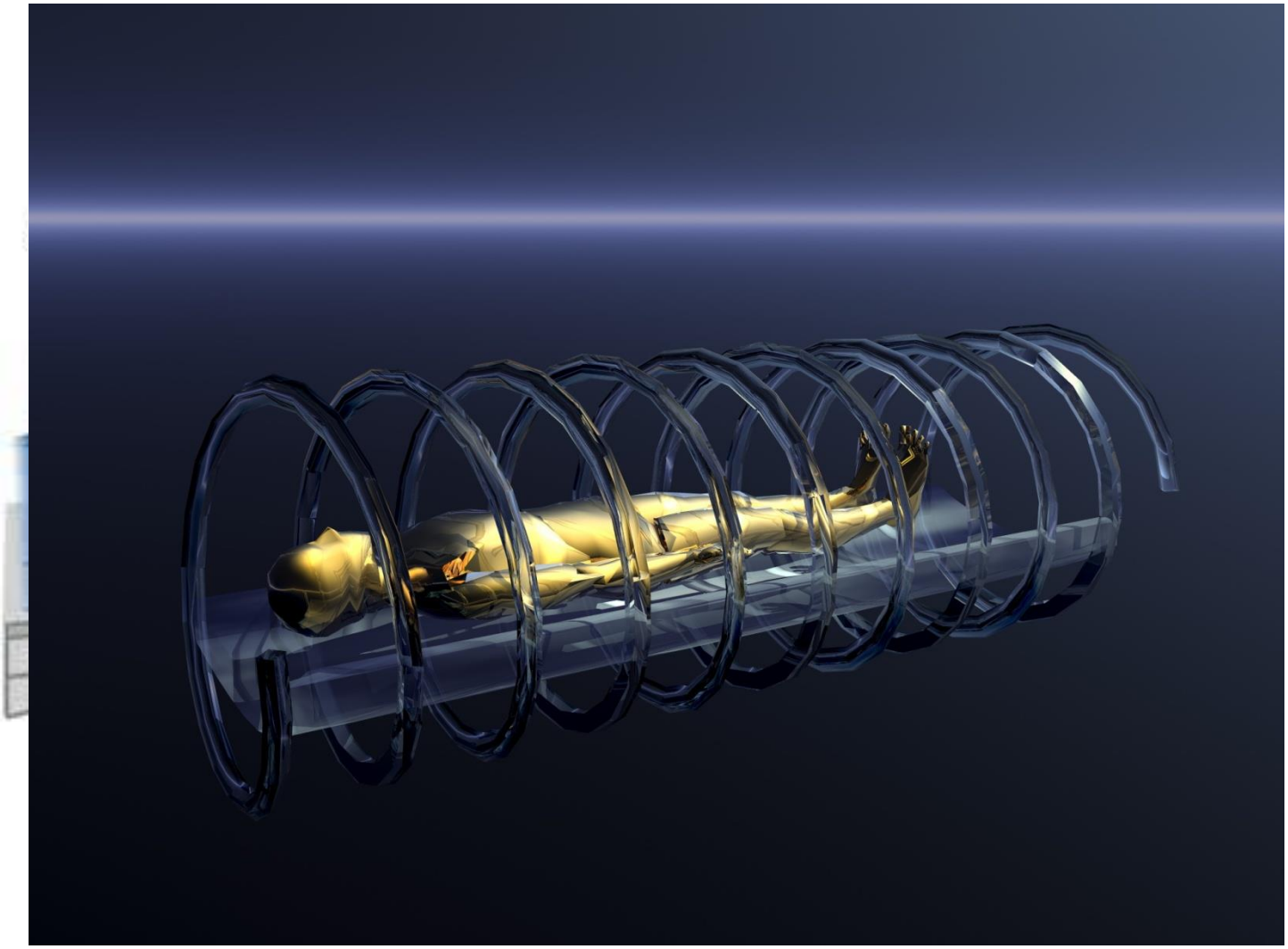


FIGURE 25-18
The Fourier Slice Theorem. The Fourier Slice Theorem describes the relationship between an image and its views in the frequency domain. In the spatial domain, each view is found by integrating the image along rays at a particular angle. In the frequency domain, the spectrum of each view is a one-dimensional "slice" of the two-dimensional image spectrum.

Cross section of a CT Scanner

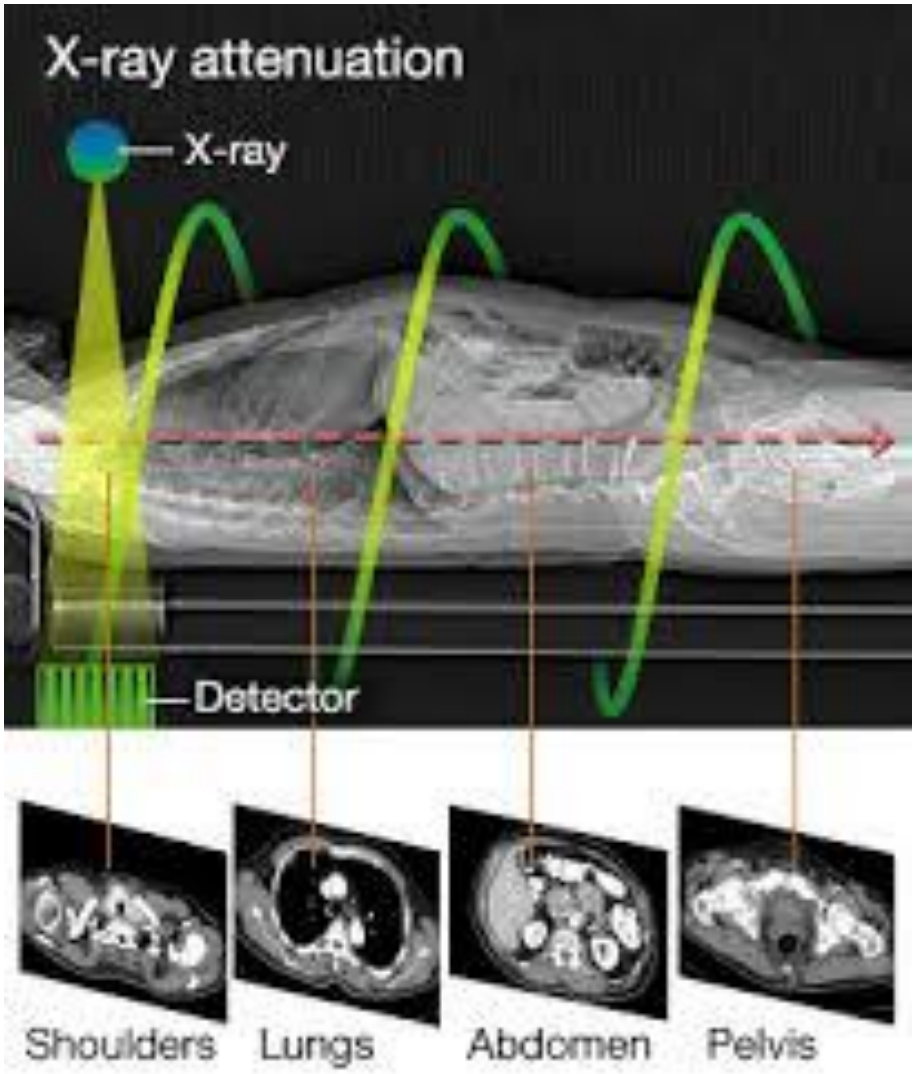


“Spiral” CT



“Volume” CT imaging

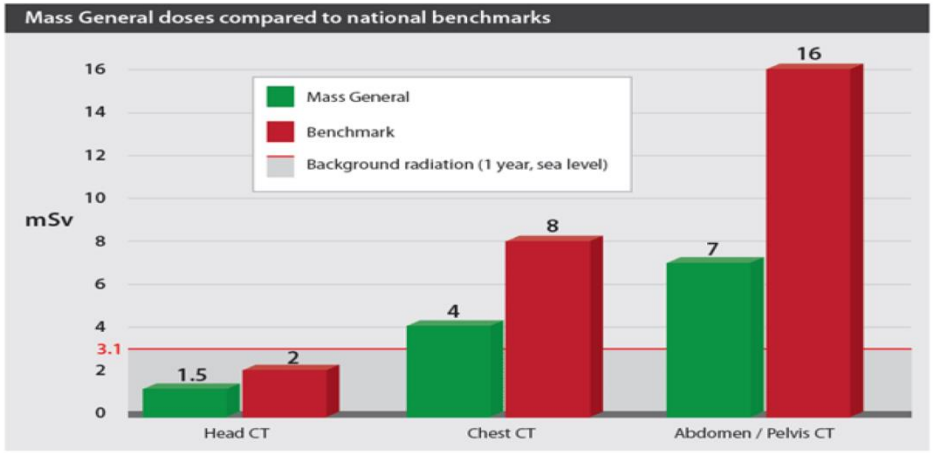
Attenuation differences thru the body



Radiation

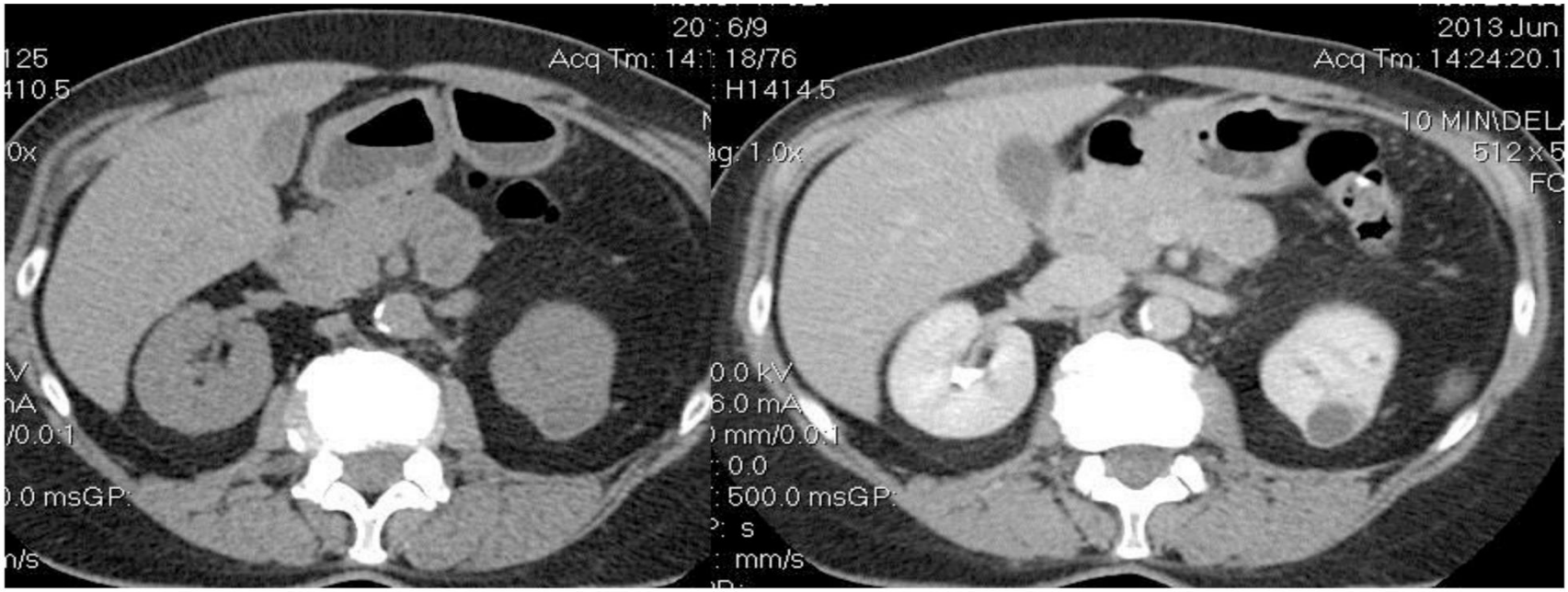
Radiation

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



Contrast Media

Iodinated Contrast Media

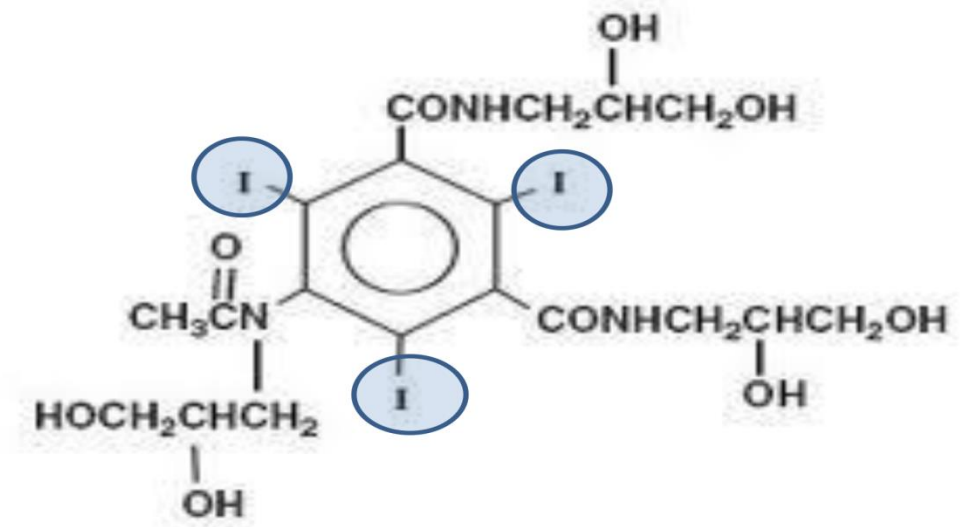


Iodinated Contrast

Iodinated Contrast

Non ionic iodinated contrast

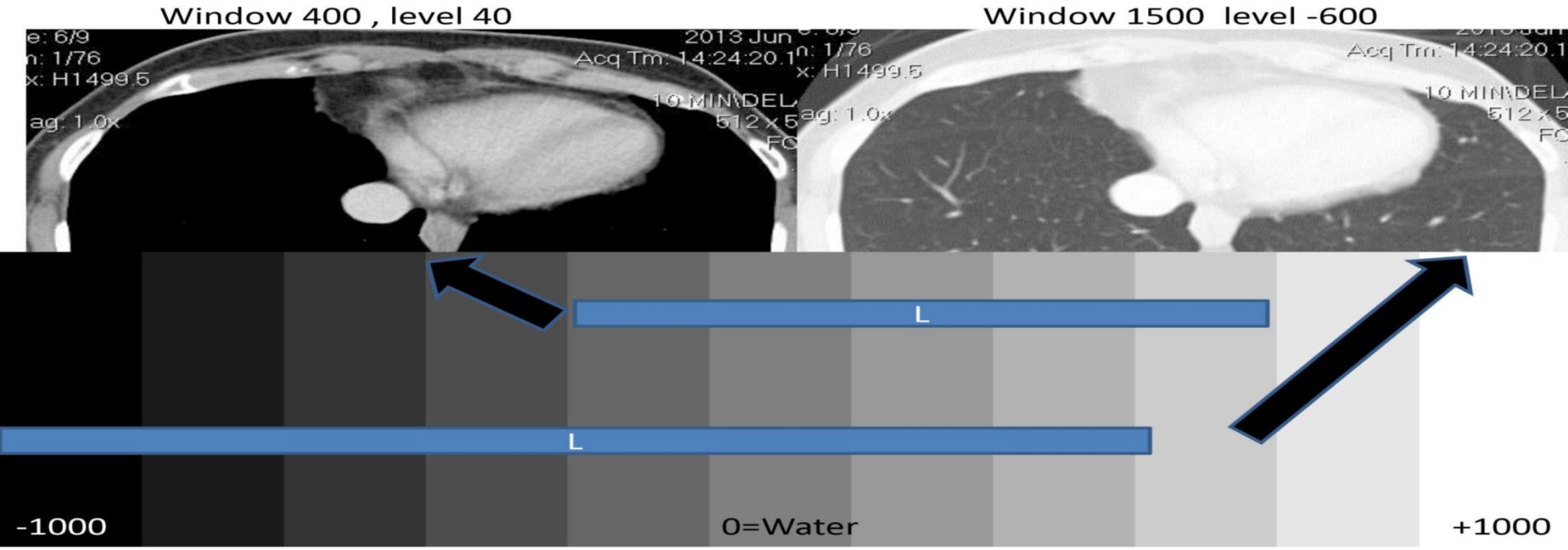
Non ionic Iodinated Contrast



CT

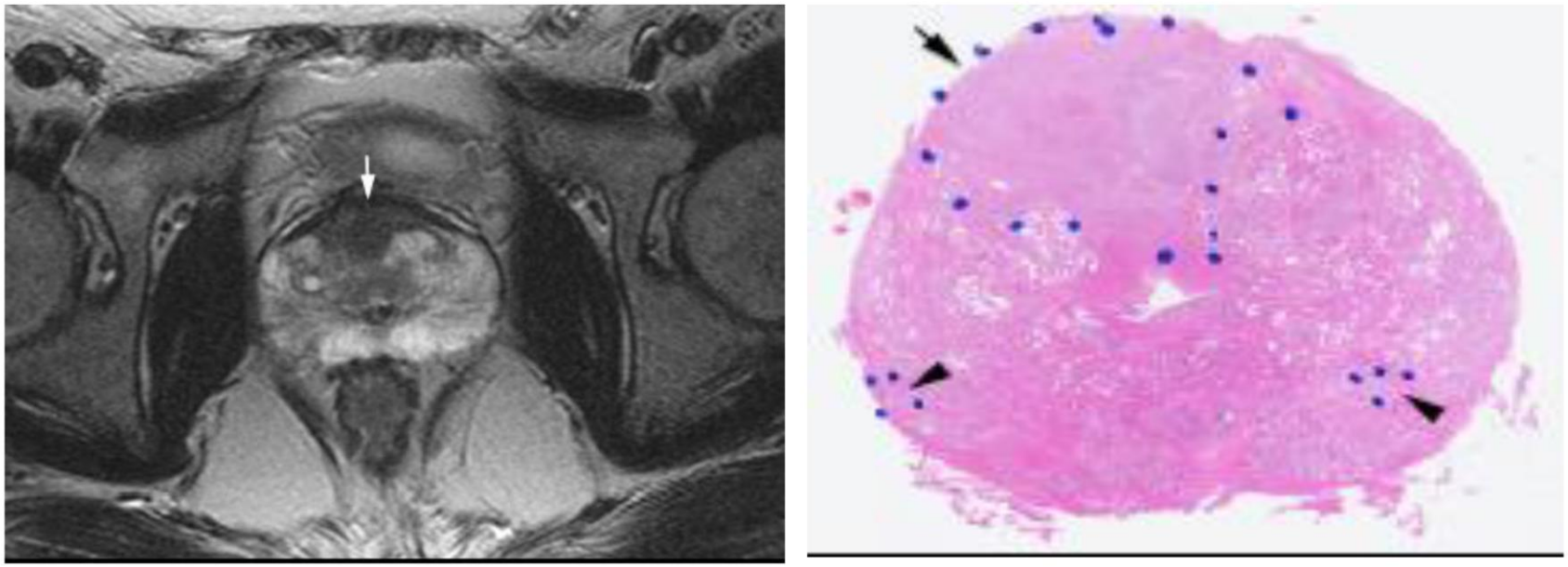
Windowing a CT

“Windowing” a CT



MRI

Magnetic Resonance Imaging



Prostate Cancer on MRI and Pathology

MRI Advantages

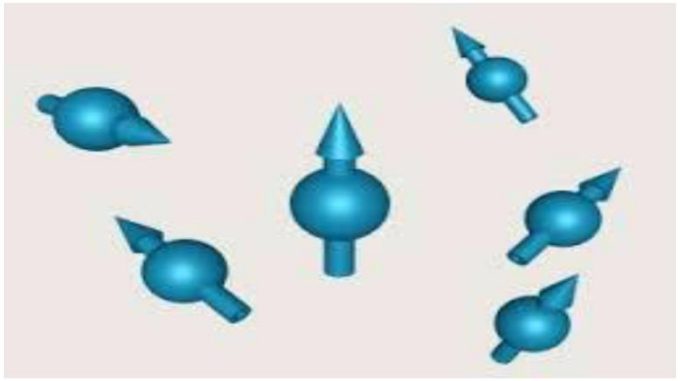
- No radiation
- Multiplanar
- Multiple contrast types:
  - T1 weighting, T2 weighting
  - Diffusion weighting
  - Contrast enhanced MRI
  - Spectroscopy

MR Disadvantages

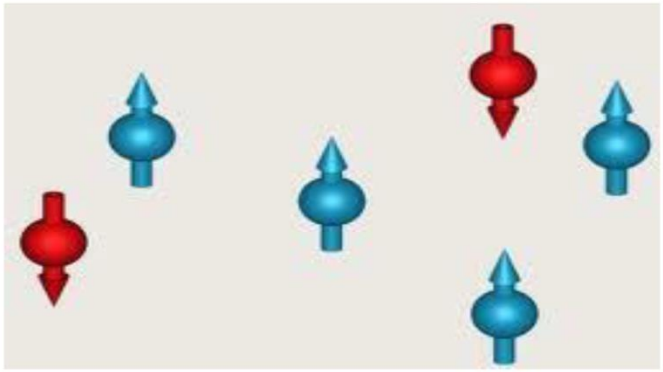
- Slower than CT
- More expensive
- Does not depict calcifications
- Safety issues
  - Metallic objects become projectiles
  - Incompatible with metallic implanted devices
    - Pacemakers
    - Cochlear implants

MRI physics

MRI Physics 101



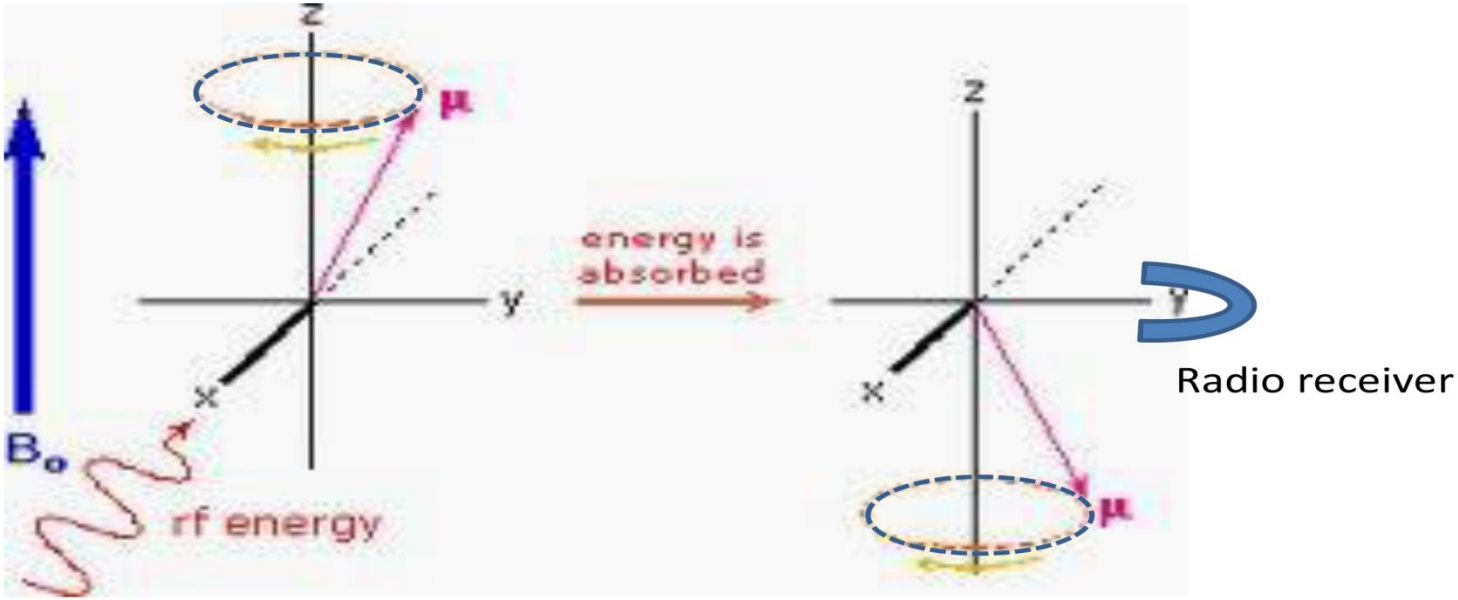
Protons in space: no field



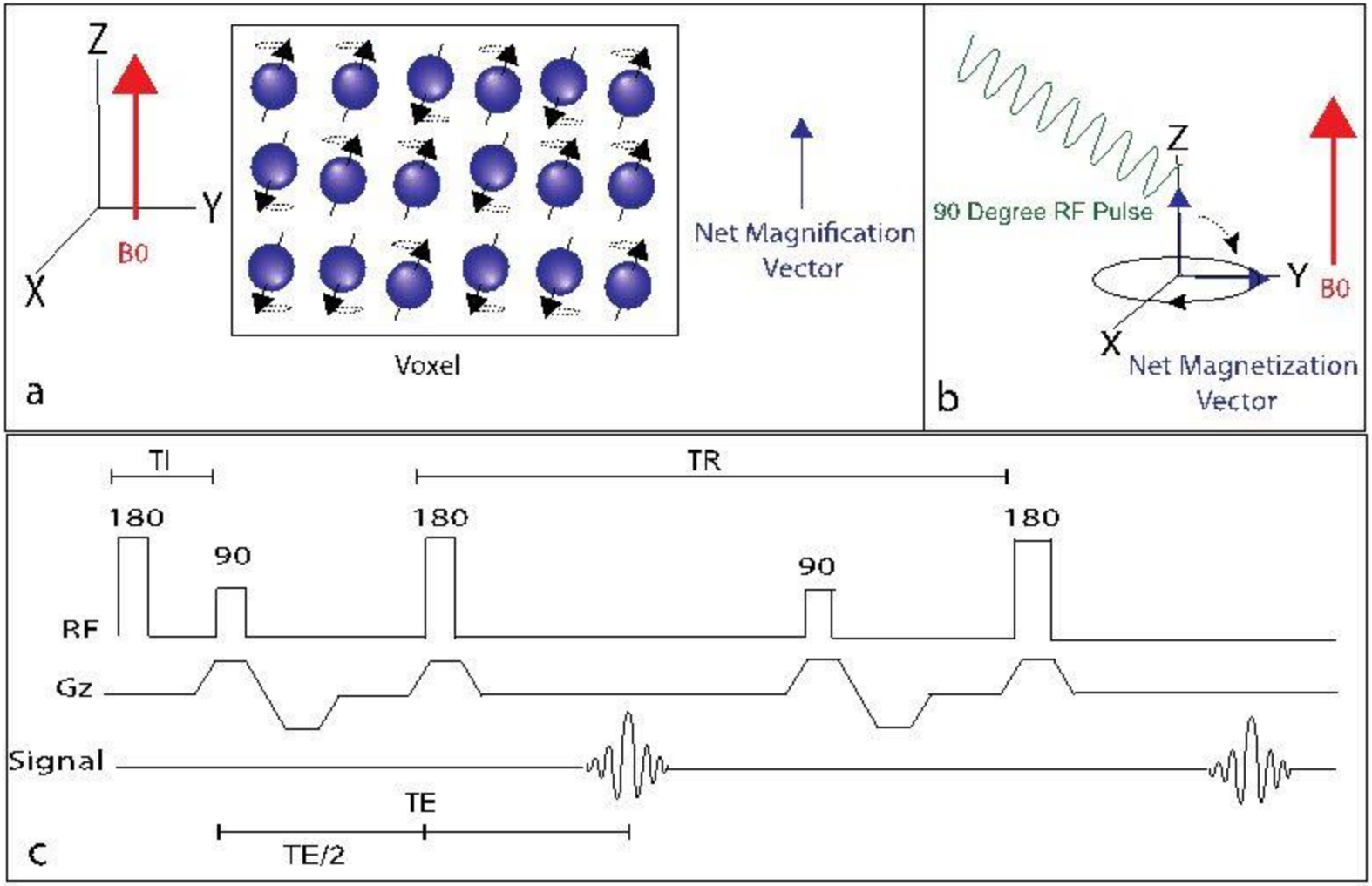
Protons in magnetic field

MR physics

MR Physics

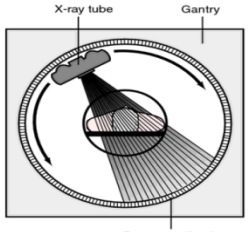


Summary

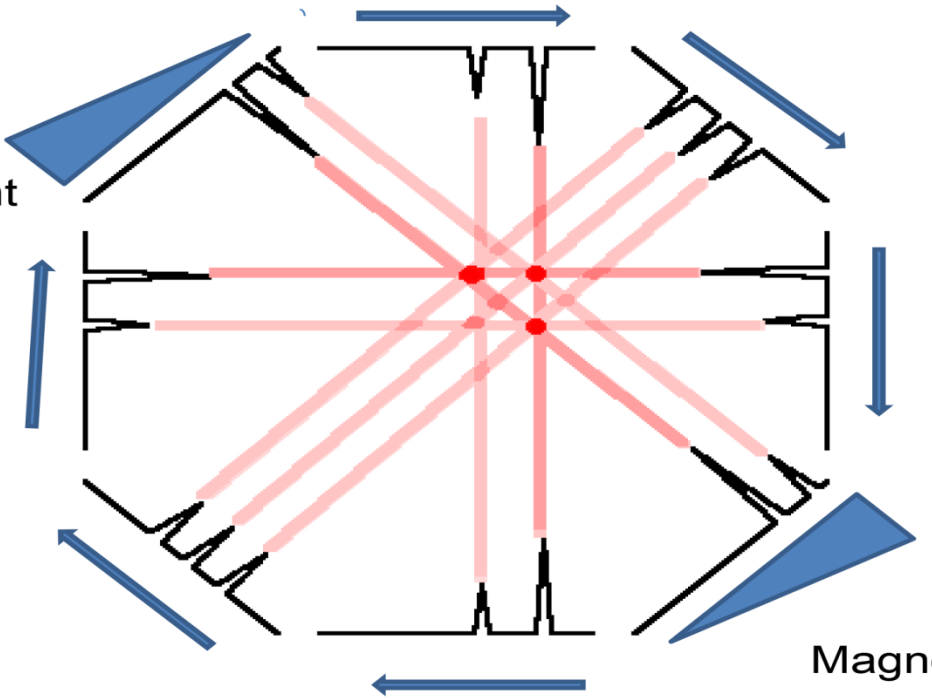

Z
Y
X
B0
Voxel
a
Net Magnification Vector
90 Degree RF Pulse
Z
Y
X
B0
Net Magnetization Vector
b
TI
TR
180
90
180
90
180
RF
Gz
Signal
TE
TE/2
c

Creating a MR Image

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

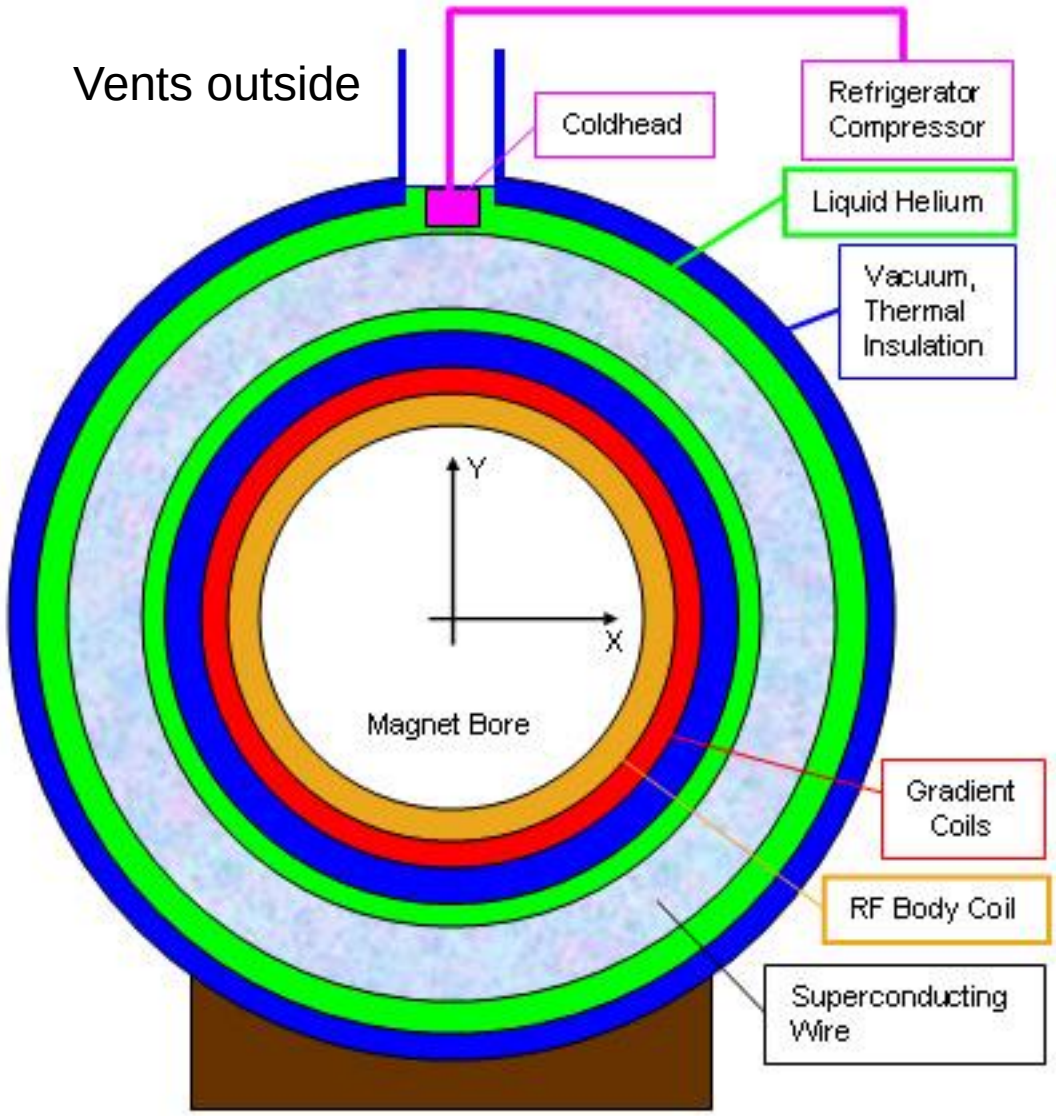


Magnetic Gradient



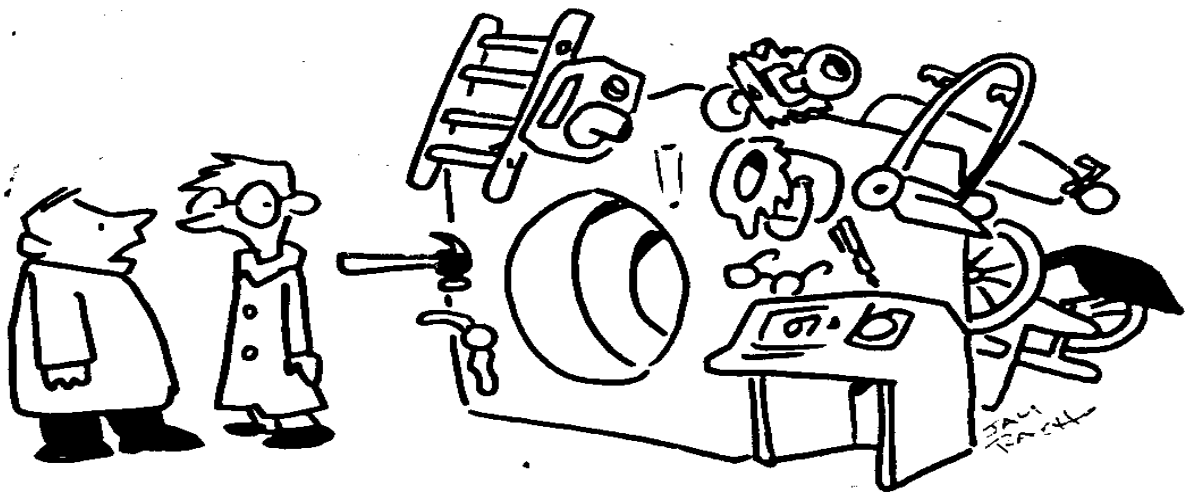
Magnetic Gradient

Anatomy of an MRI



Safety issues in MRI

The Importance of MR Safety

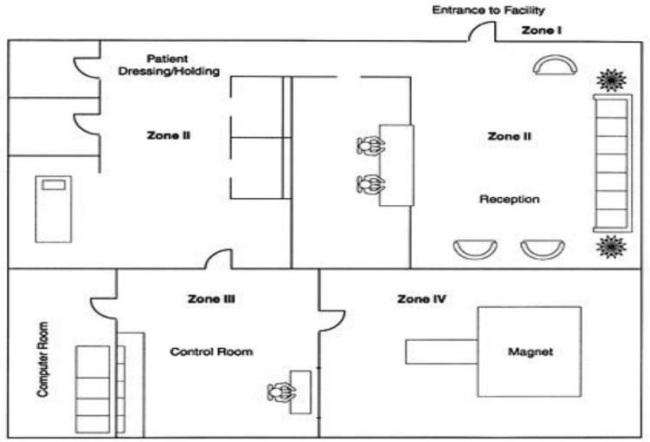


"Maybe it is time for us to review the magnet safety instructions."

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

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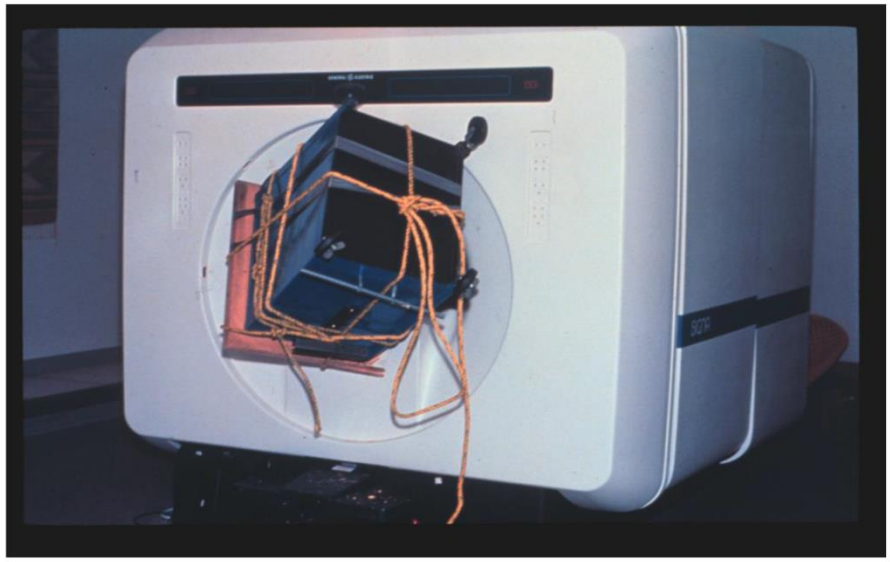


Oxygen tank

O2 Tank, "Missile"

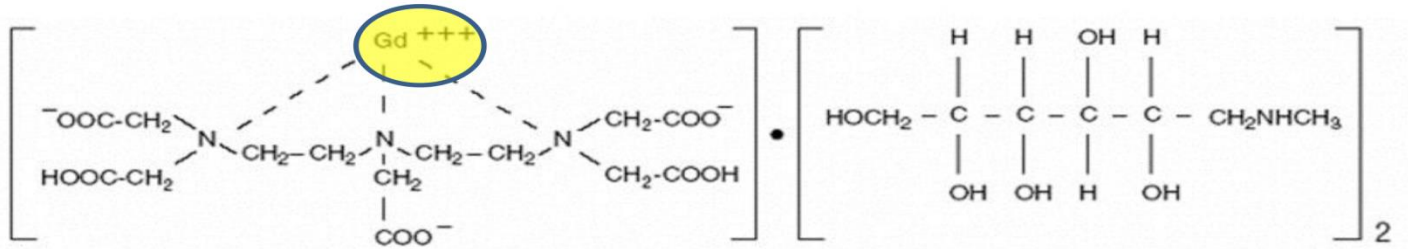
An Oxygen tank can become an Airborne torpedo in an MRI

- ed
- en

Value of Contrast Media

Gd reagents

a



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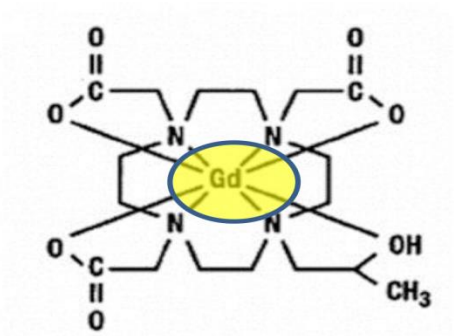

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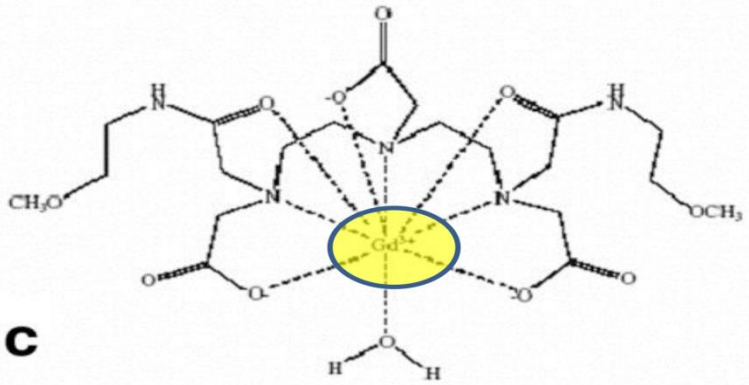

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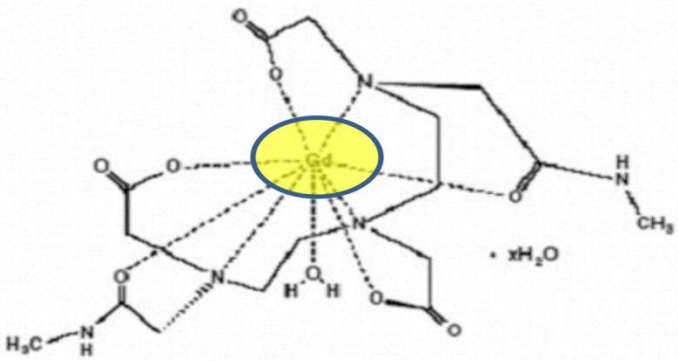
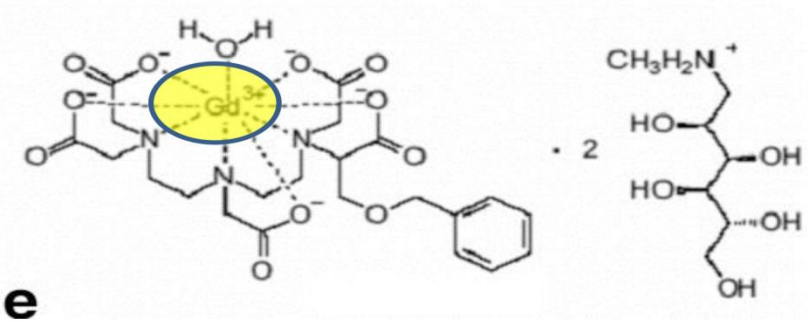


e



GD reagents

GD Reagents

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

Nephrogenic systemic sclerosis

Examples: nephrogenic systemic sclerosis

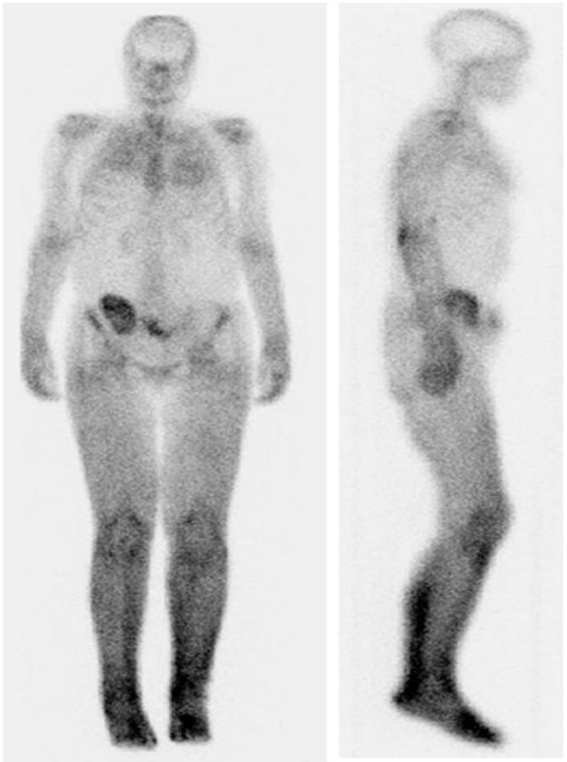
AJR 188 Feb 2007

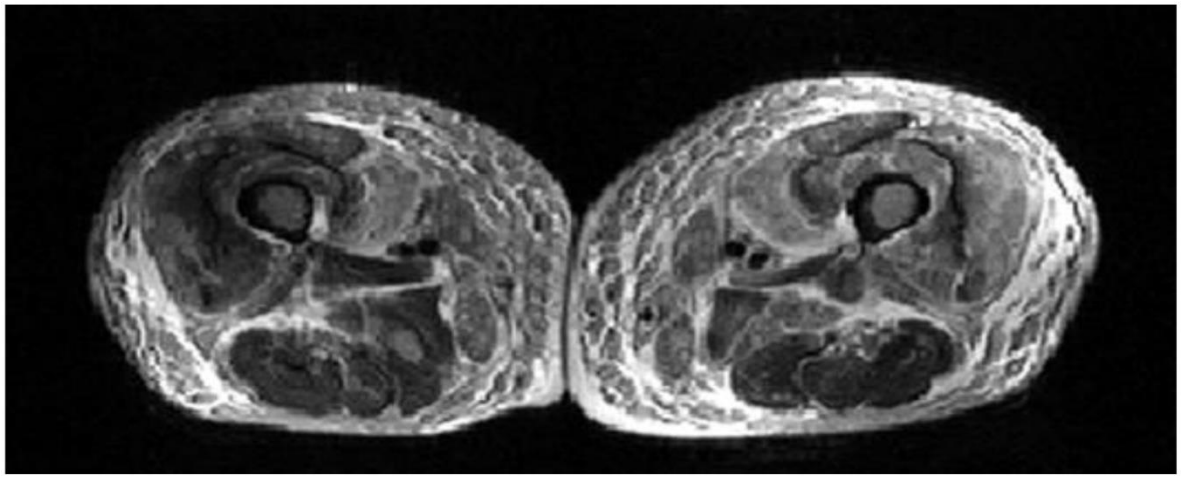
Nephrogenic Systemic Fibrosis (NSF)

- May 2006 Danish Medicine Agency reported 25 cases of NSF in patients in renal failure who received gadodiamide (~2m)
- Nov 2006 Loma Linda reported 12 (8 on dialysis) NSF patients receiving 0.2mmol/Kg gadodiamide within 2-8 weeks of injection
- Since then over 200 cases have been reported with all of the available contrast agents but mostly Omniscan and Optimark
- By 2013 almost no cases are reported

Case of NSF

Case of NSF





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Mechanism

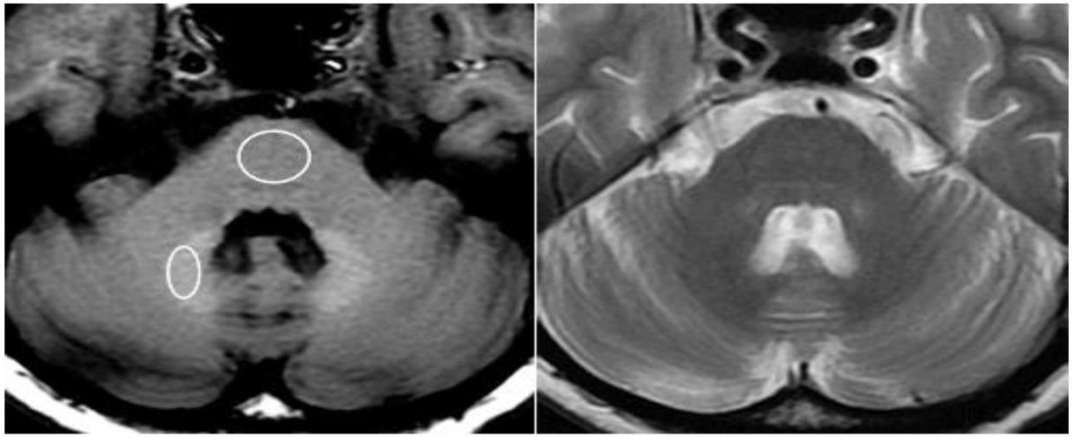
- Gadolinium is highly toxic
- Patients with normal renal function excrete Gd-chelates within 24-48h
- Patients with abnormal renal function may take weeks to excrete the agent
- Dissociation of Gd from the chelate could deposit in soft tissues (documented)
  - Hugh et al. Tissue Gd conc .14-24 ng/mL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

Risk Factors

- Renal failure:
  - Dialysis
  - Chronic renal failure (GFR <30cc/min)
- Dose
  - Double, triple (vs. half dose)
- Contrast agent
  - Omniscan>Optimark>Magnevist>Prohance>
- Alternative imaging?
  - Non con MRI
  - CT, US, PET

Residual Gd

Residual Gadolinium!



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Ultrasound


11.04.2004
RAB4-8-D/C8
MI 1.1
Dr. Manoder ecofotolo.com
TIS 0.1
02.02.2012
12:41:36
CRL
CRL 6.81cm
GA 12w6d 71.6%

US advantages

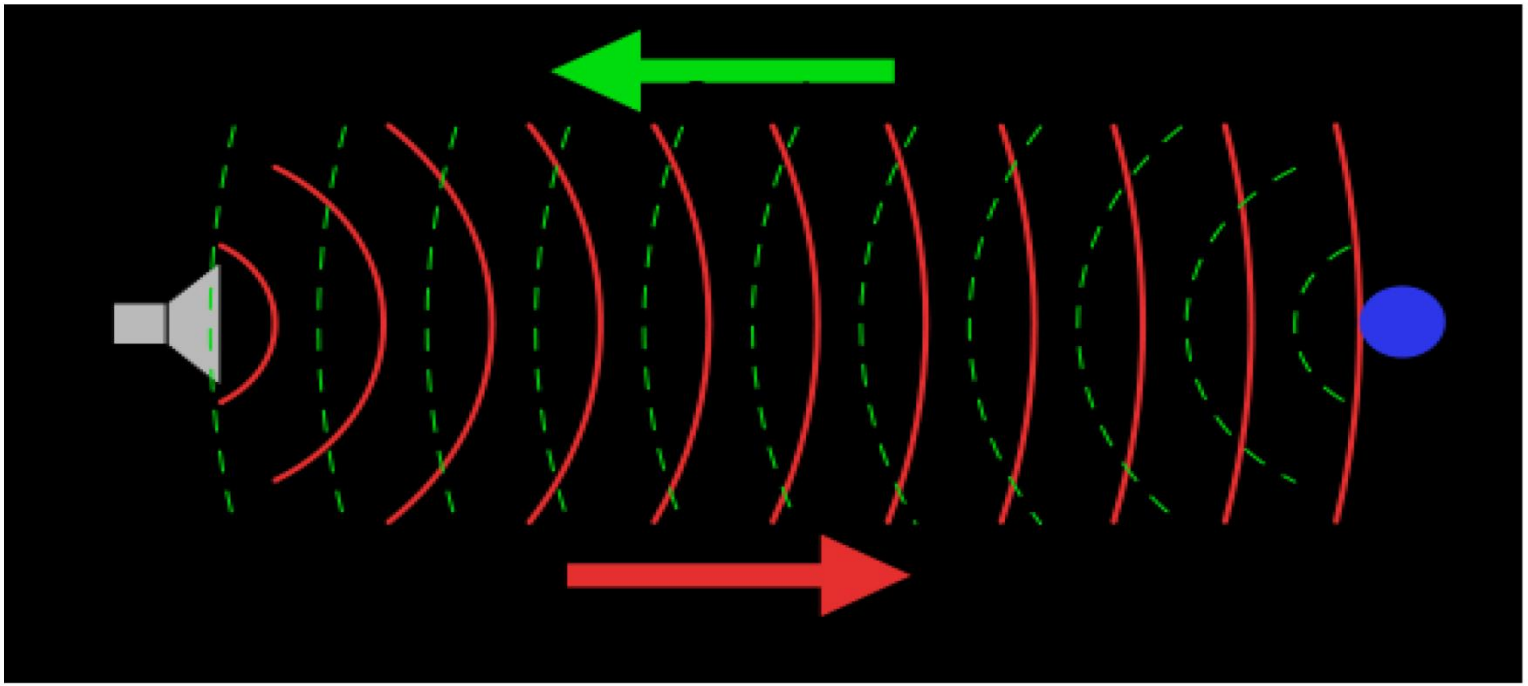
- No radiation
- Real time
- Inexpensive
- Quick, little prep
- No injection

US disadvantages

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

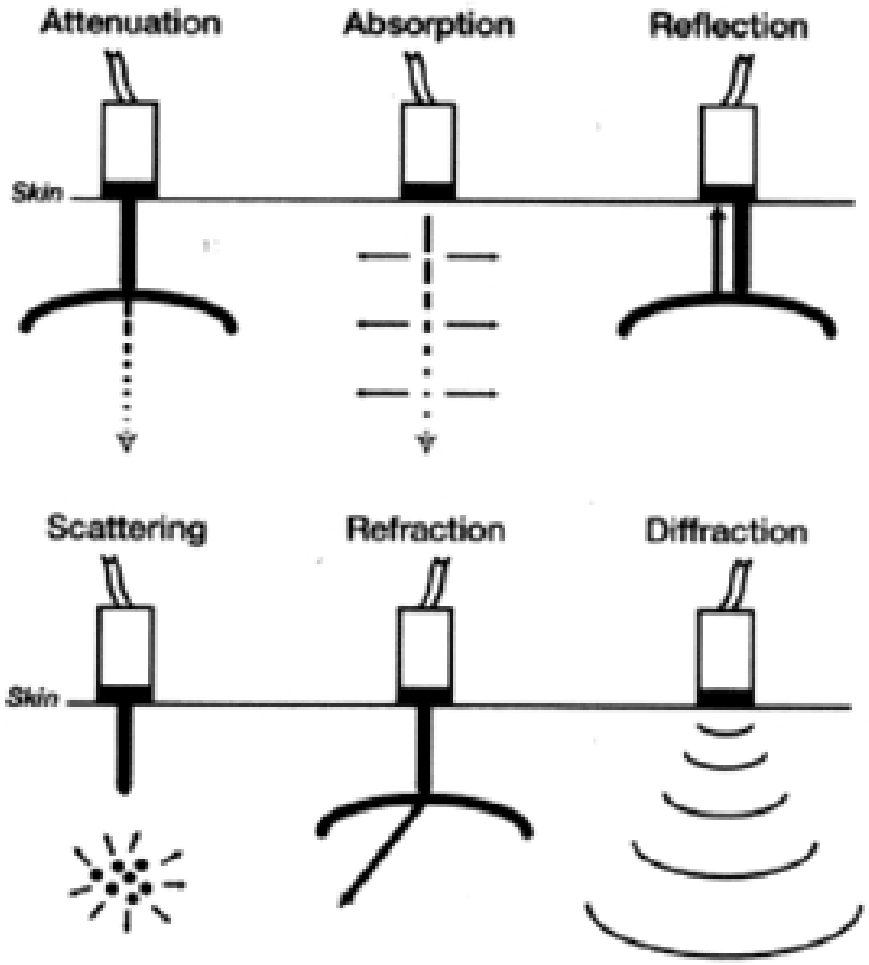
Ultrasound basics

US basics

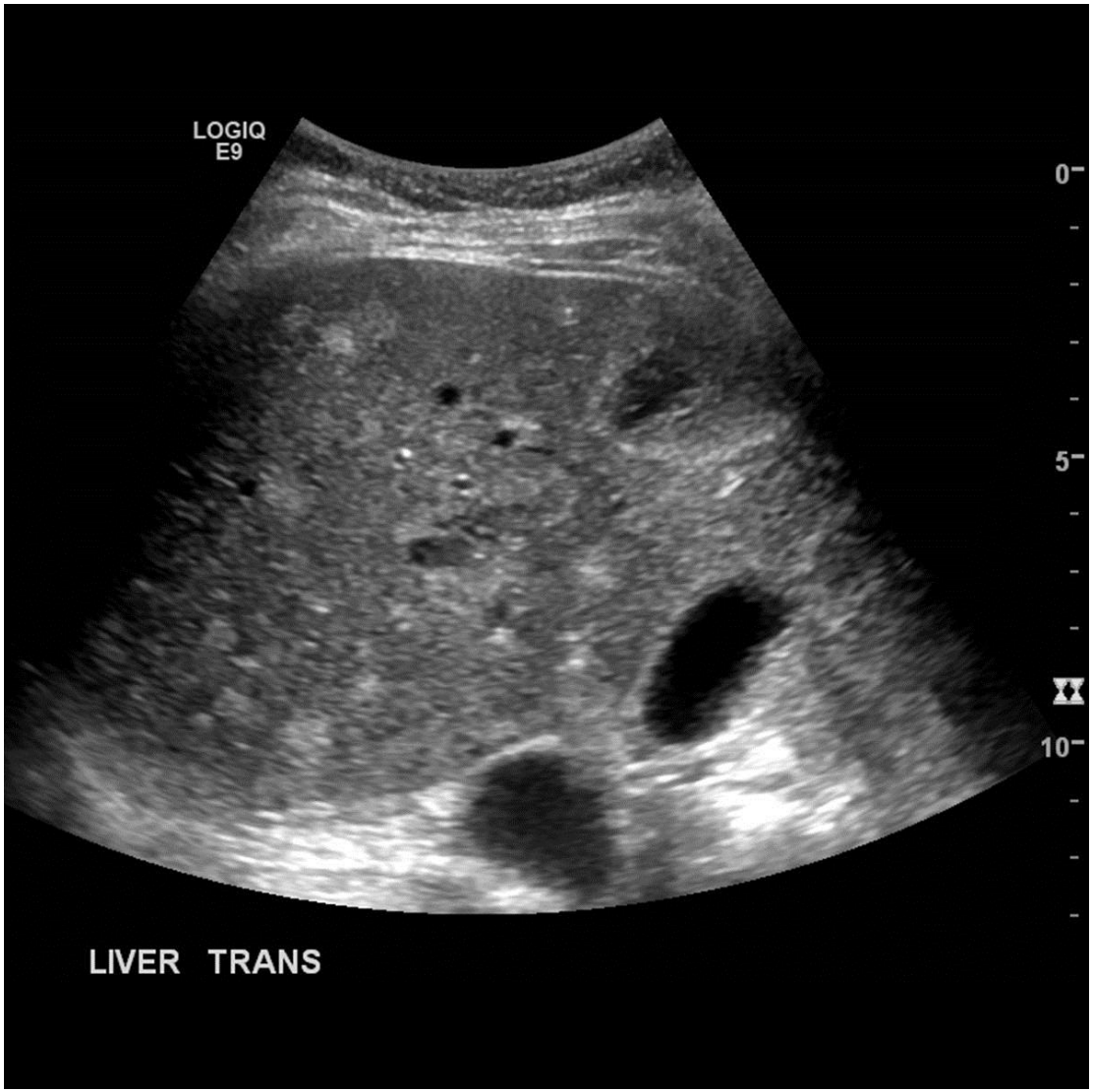


Imaging dependent on the speed of sound
In tissue

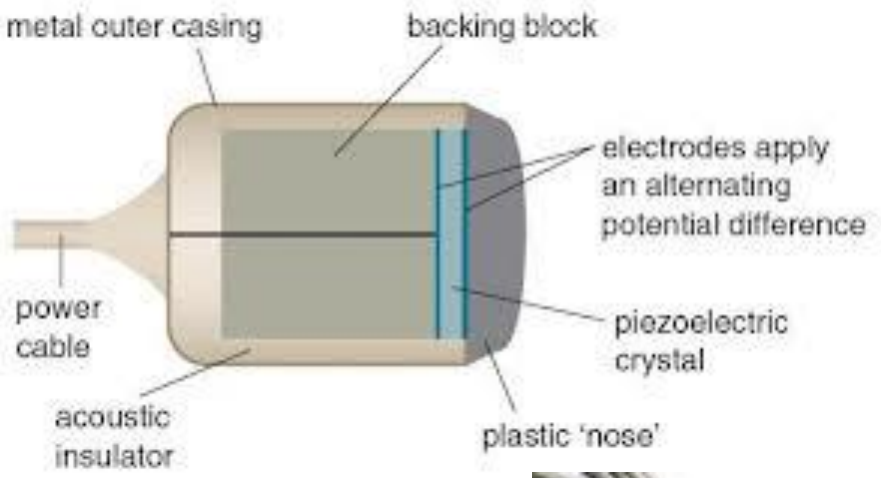
Fate of sound waves in body



Liver metastases

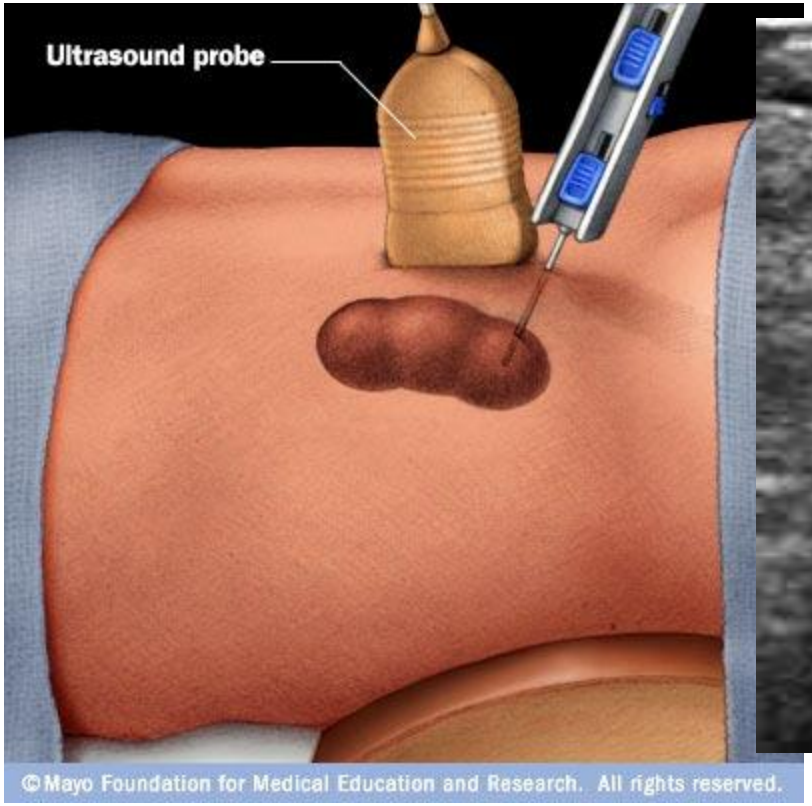


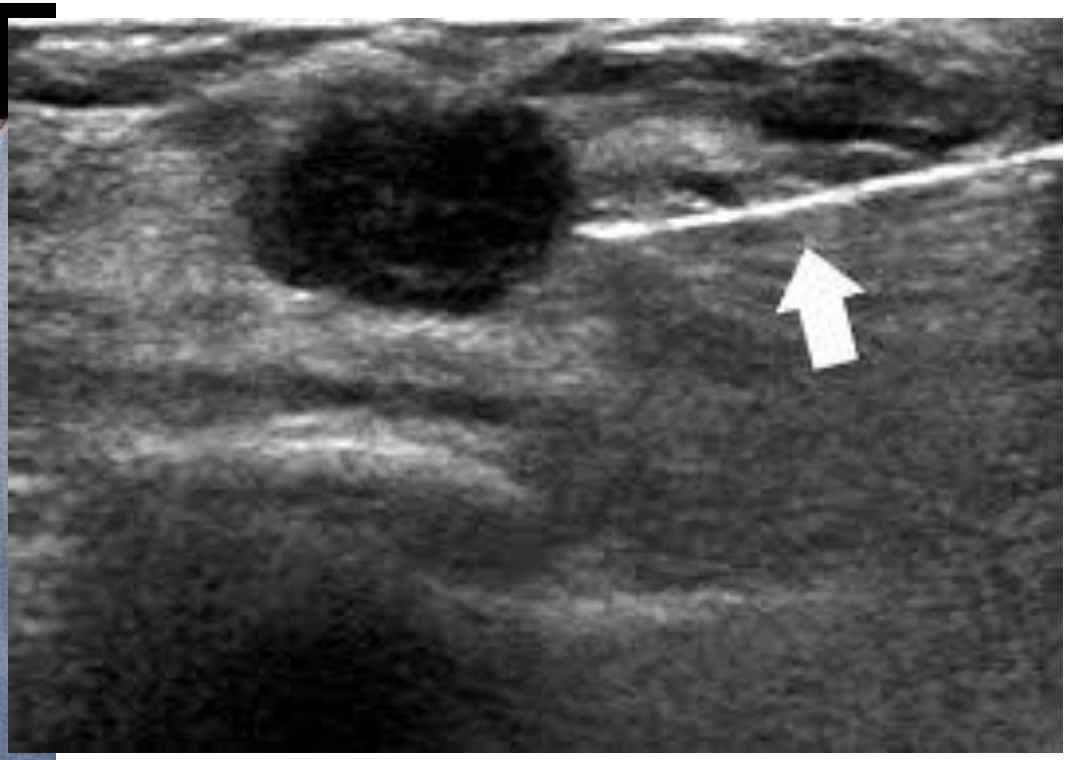
US Probes


metal outer casing
backing block
electrodes apply an alternating potential difference
power cable
piezoelectric crystal
acoustic insulator
plastic 'nose'

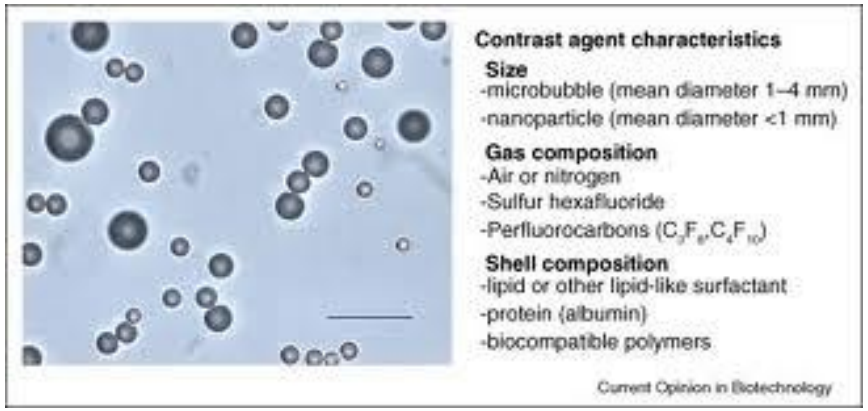
Evolution of US devices

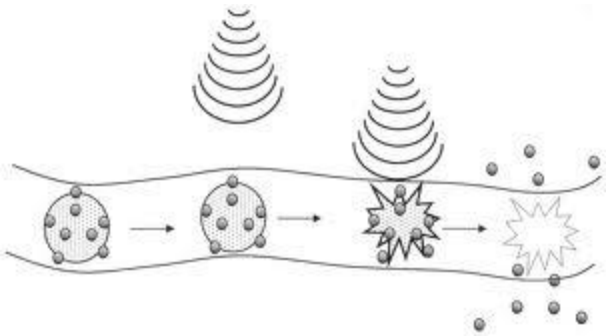
US guided biopsy-real time





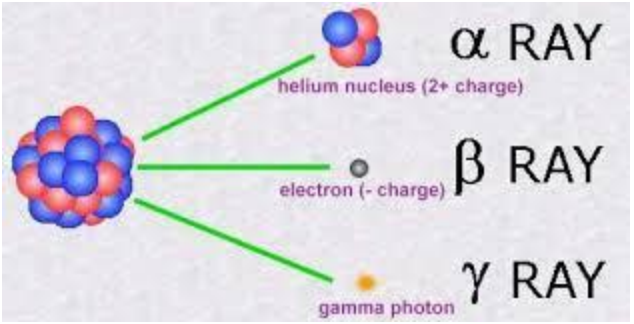
US Microbubble contrast





Single Photon Emission Computed Tomography-SPECT

- Single Photon Emission



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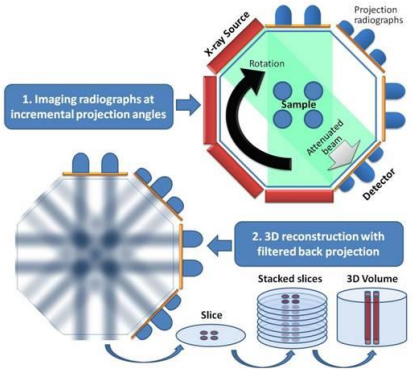
- Computed Tomography

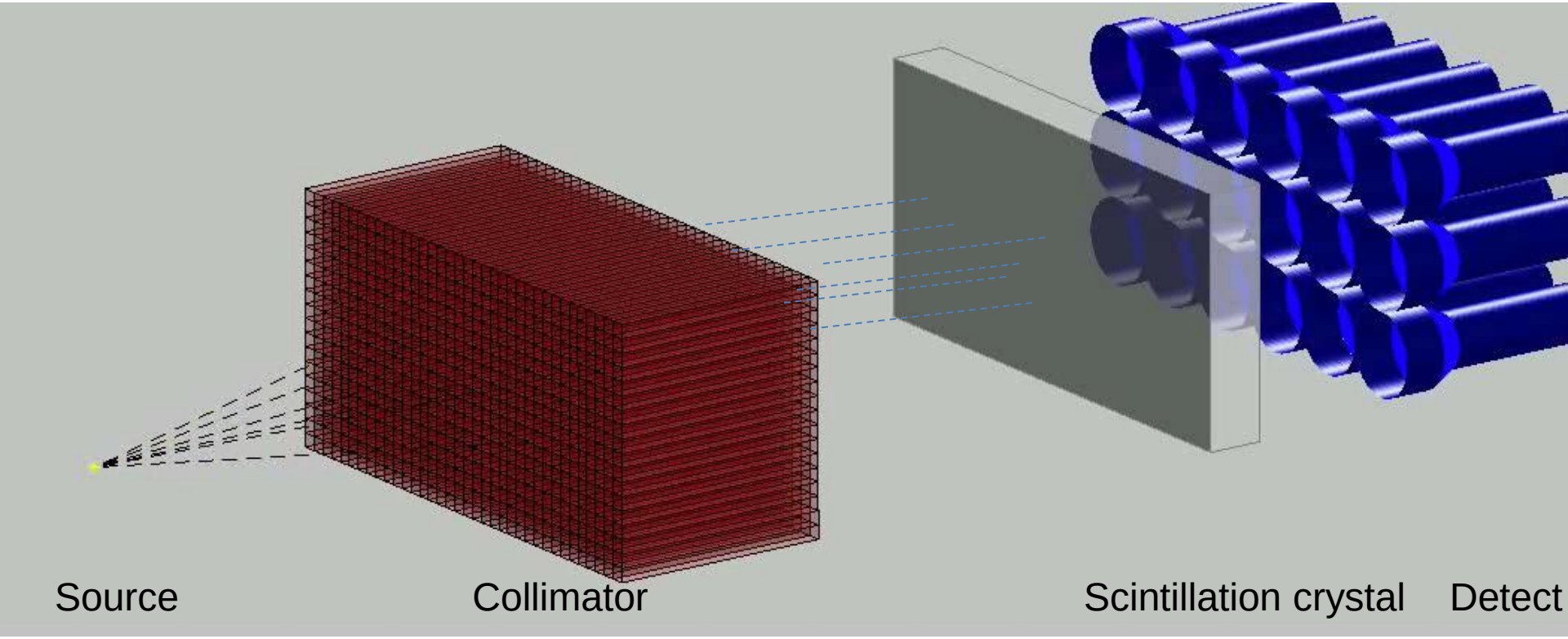


SPECT Advantages/Disadvantages

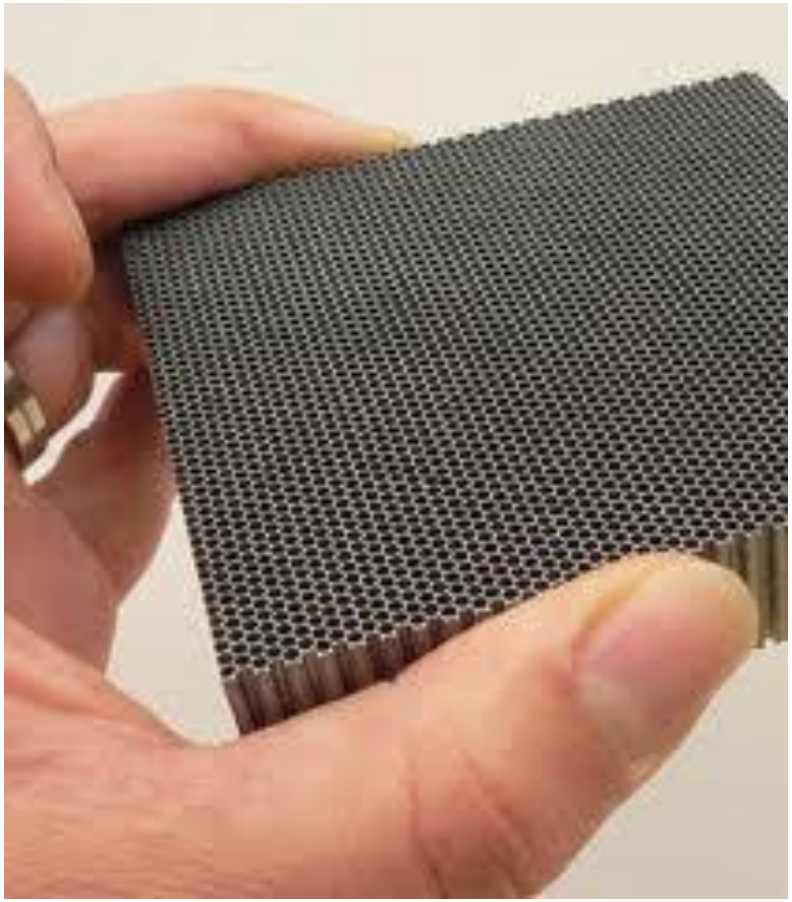
- Relatively inexpensive
- Broad experience

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

SPECT detectors



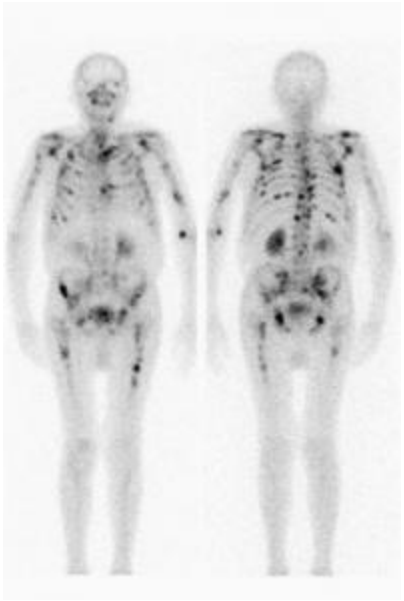
Collimation cont’d



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

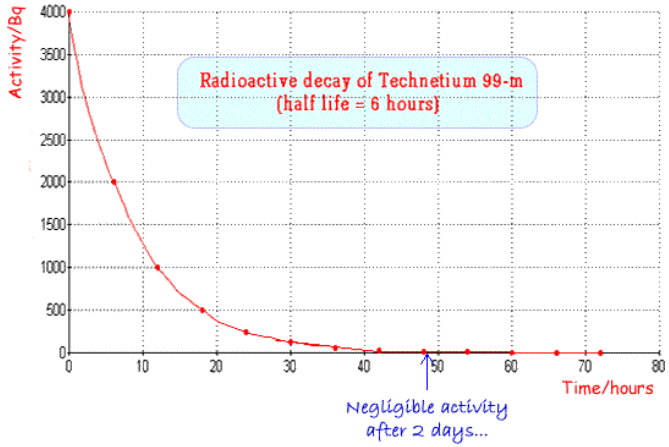
SPECT Imaging

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



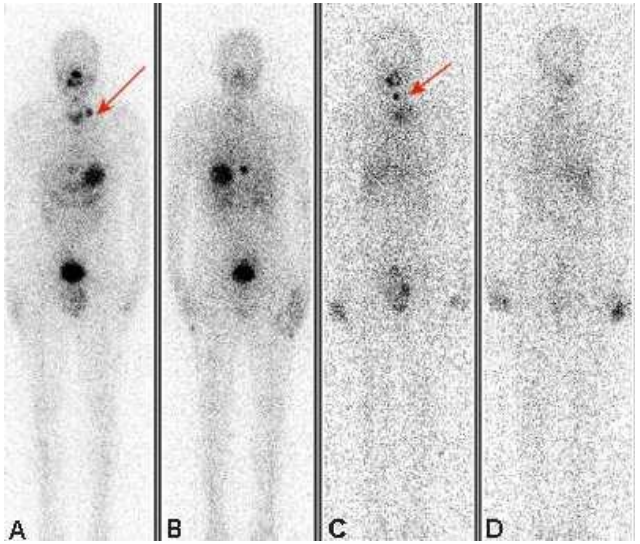
The bone scan:

^{99m}Technetium-methyl diphosphonate

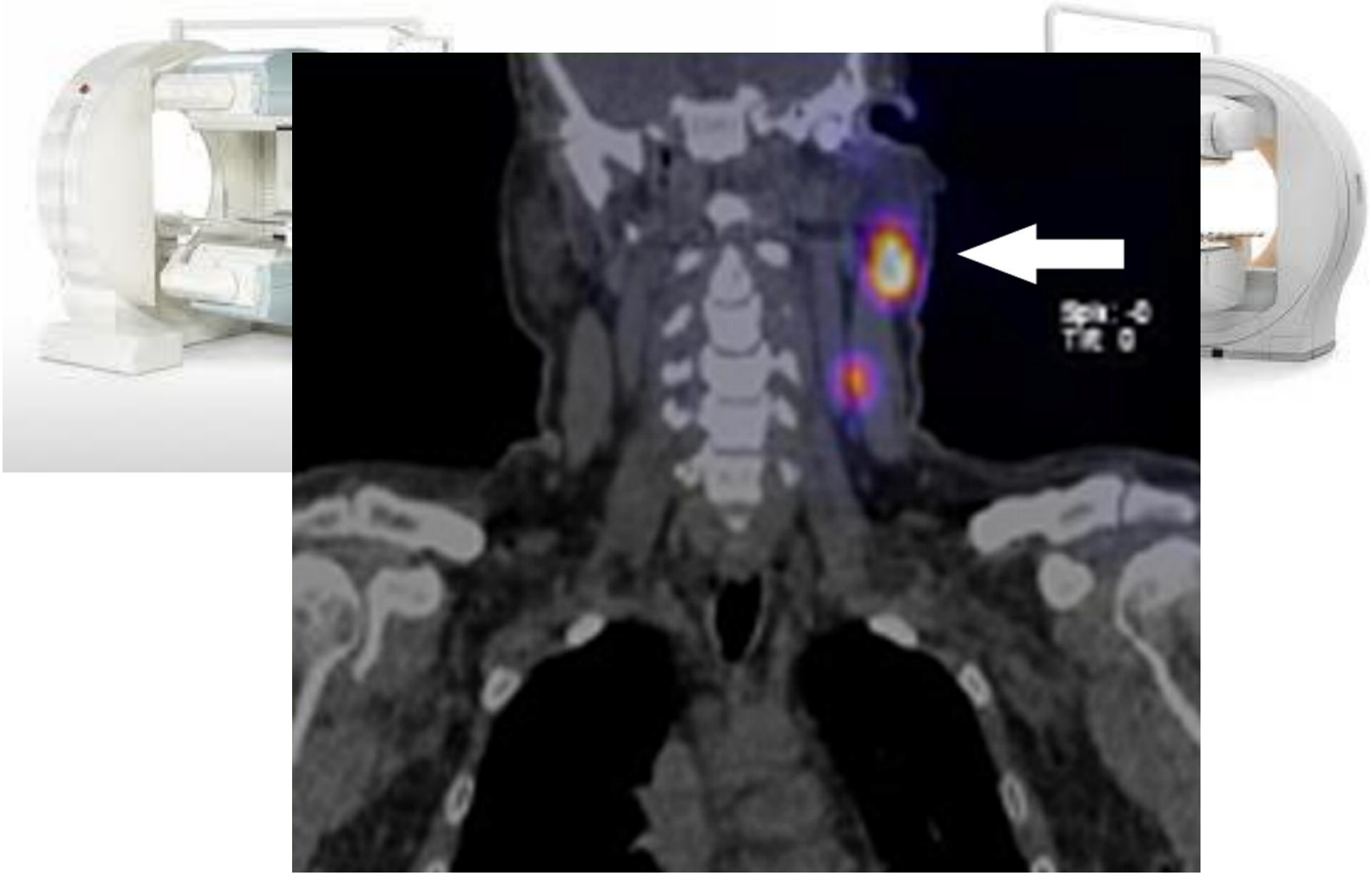


SPECT agents for cancer

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

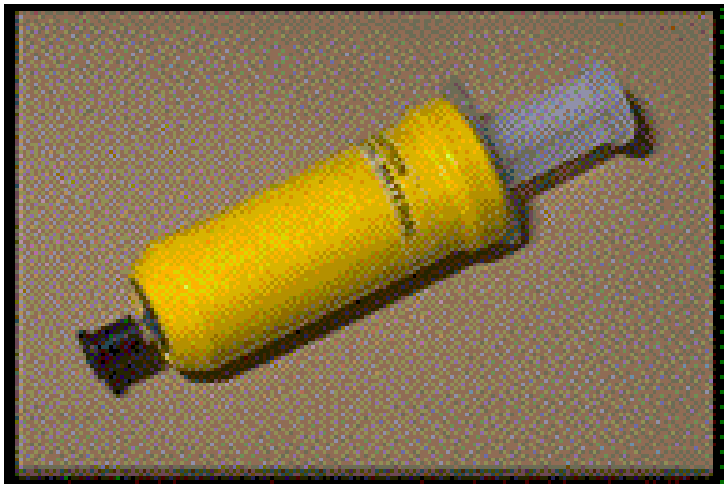


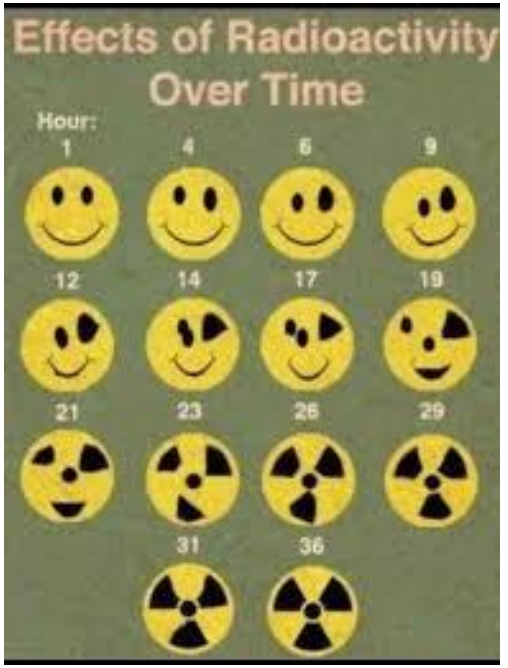
Hybrid Imaging



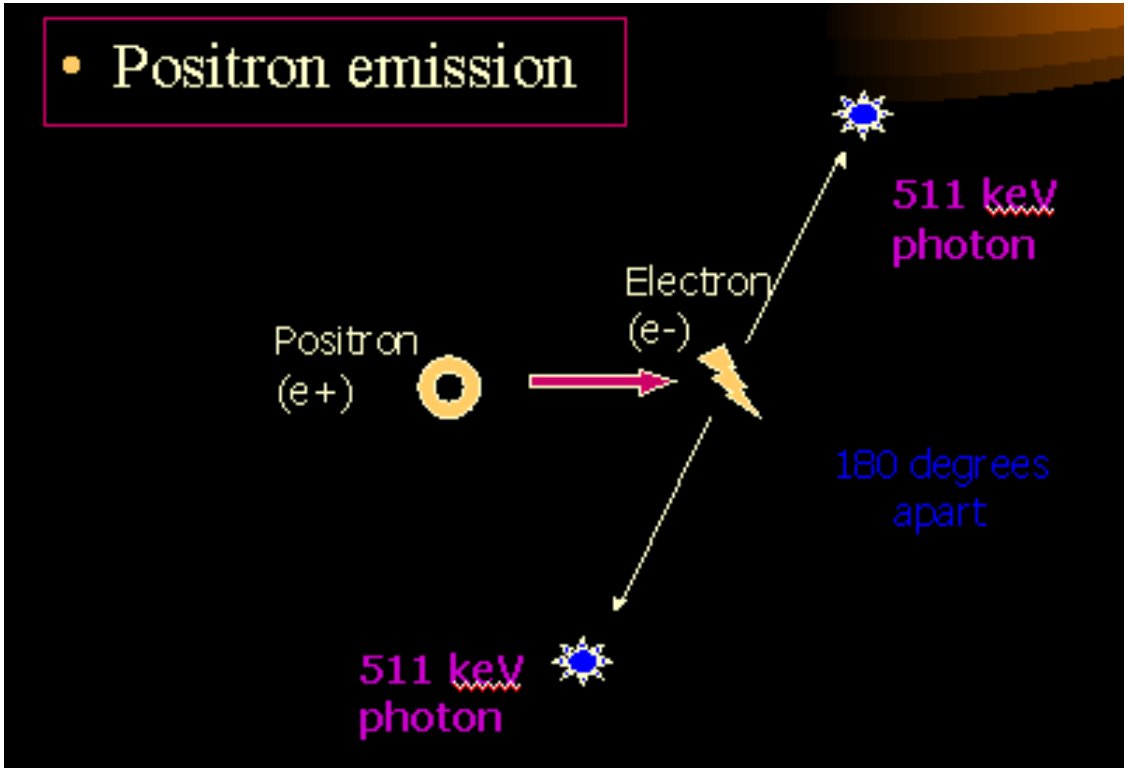
Safety

- Operator
- Patient





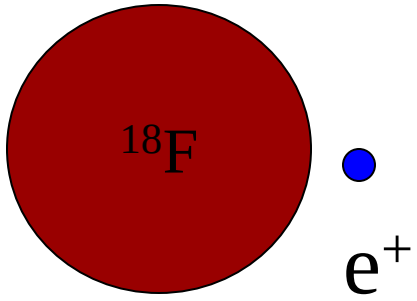
Positron Emission Tomography

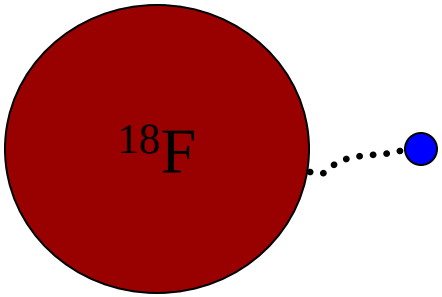


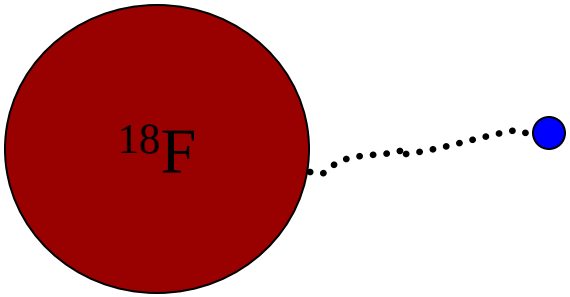
PET:Advantages and Disadvantages

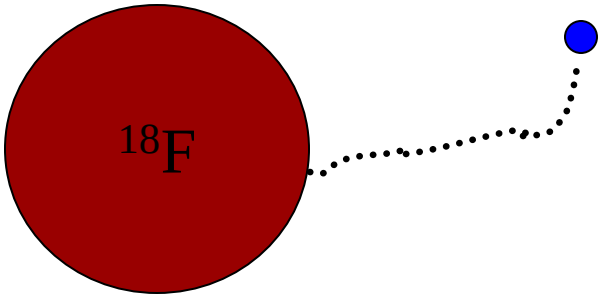
- Highly sensitive
- Metabolic information
- Better spatial resolution than SPECT
- Combined with CT
- _____
- Expense
- Regulatory
- Short half life

Positron Emission Tomography




^{18}F


^{18}F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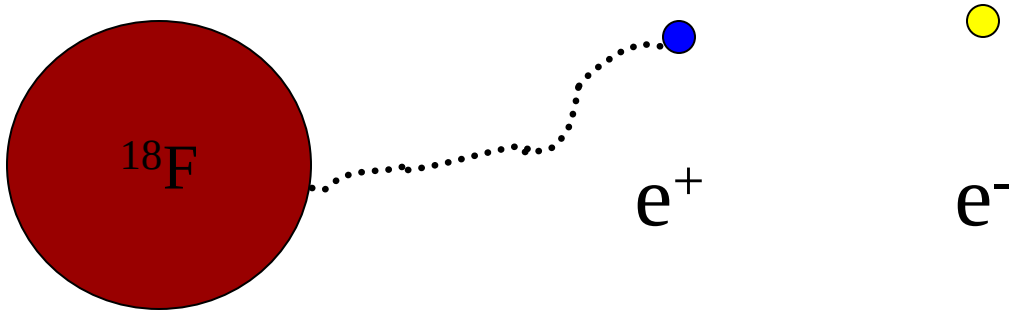
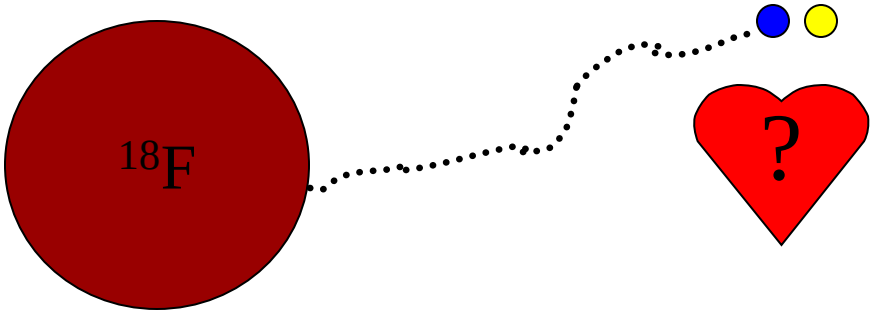
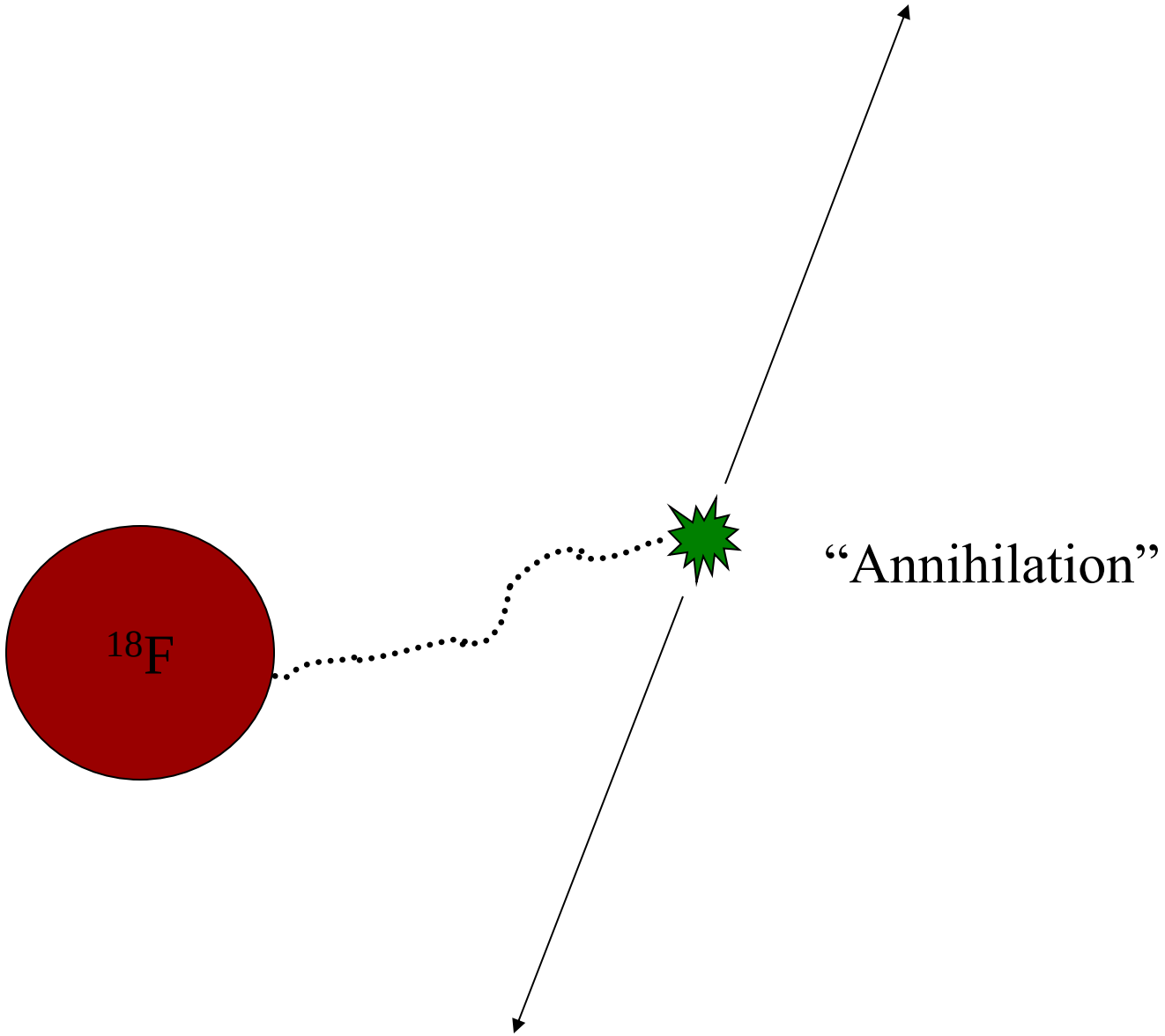
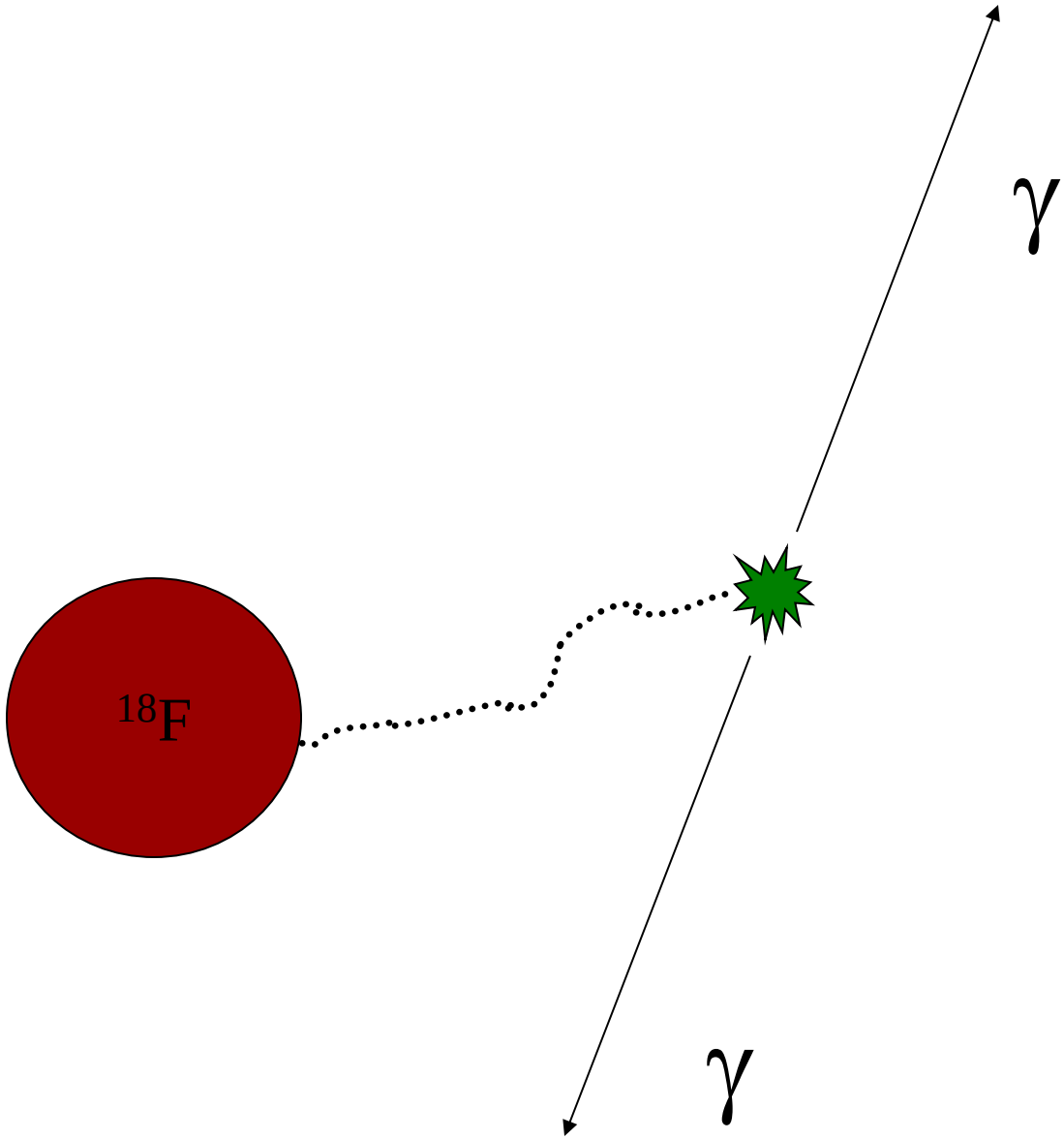
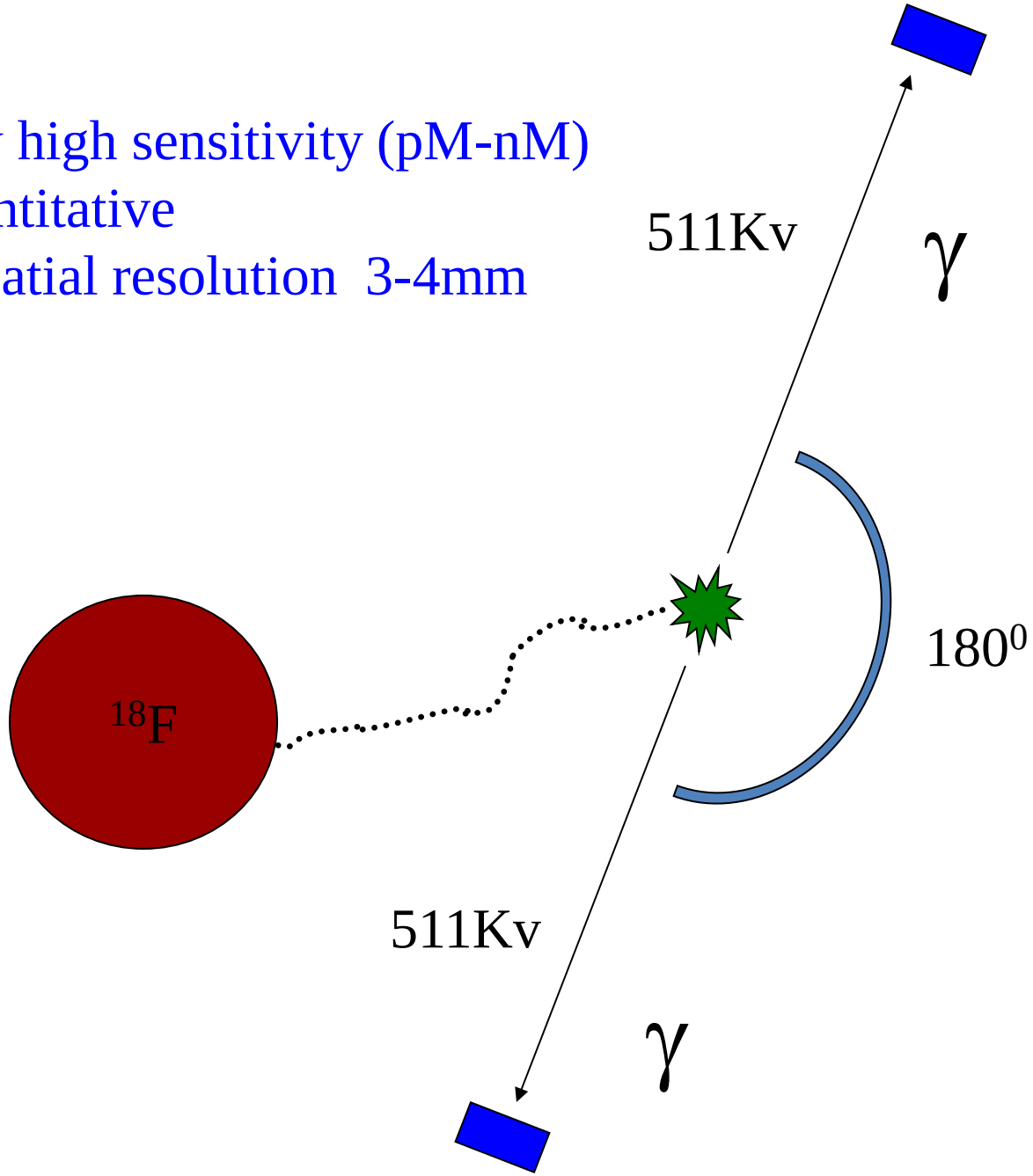

^{18}F
e^+
e^-


^{18}F
?


^{18}F
"Annihilation"


^{18}F
γ
γ

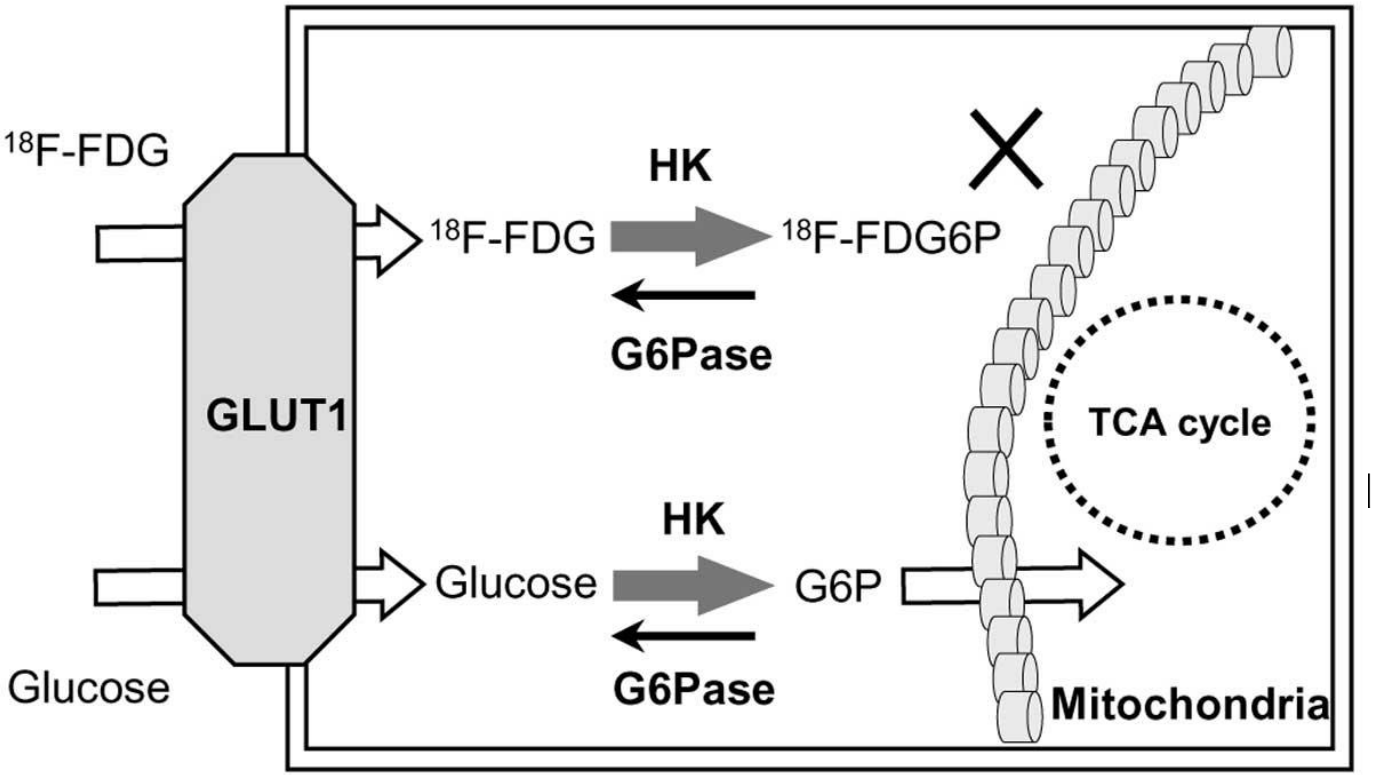
Very high sensitivity (pM-nM)
Quantitative
± Spatial resolution 3-4mm



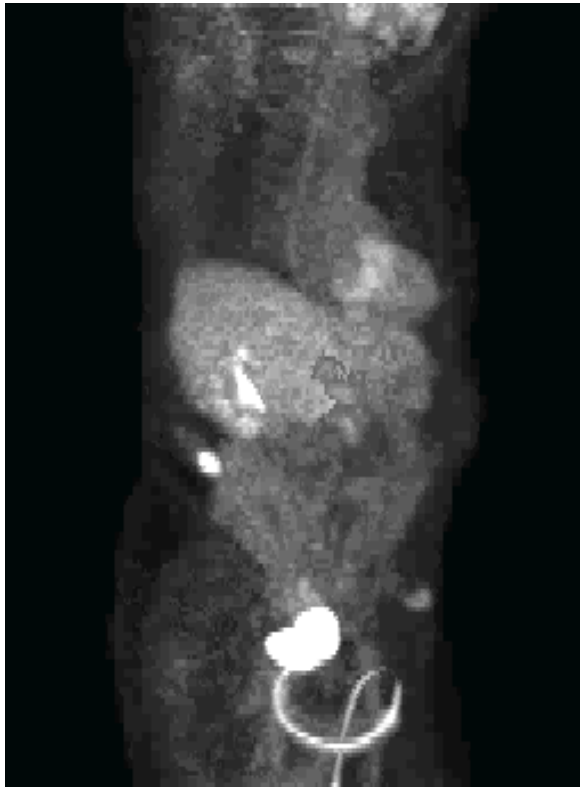
F-18 Deoxyglucose

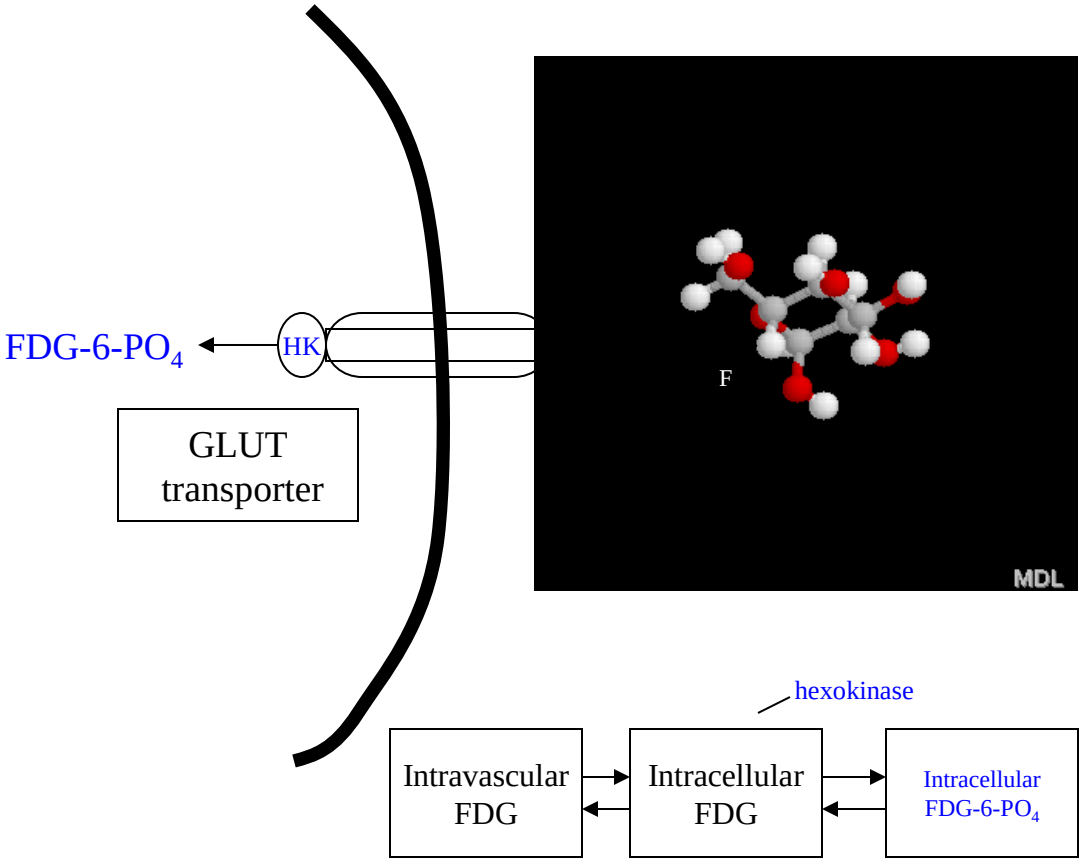
Otto Warburg

Lou Sokoloff



^{18}FDG PET Imaging

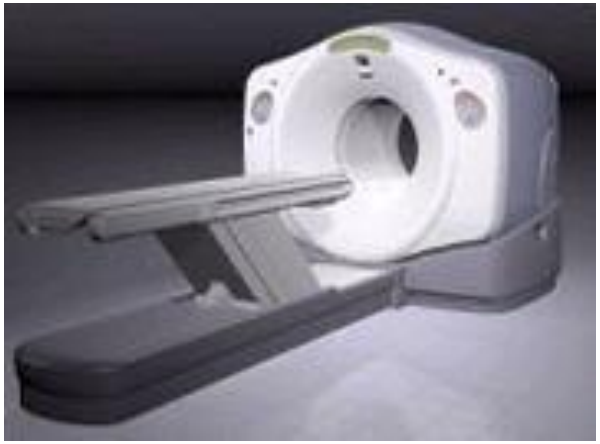




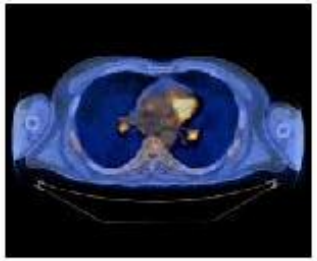
Facilitate Advanced Imaging Technology

- Positron Emission Tomography
  - PET-CT Device

PET Image

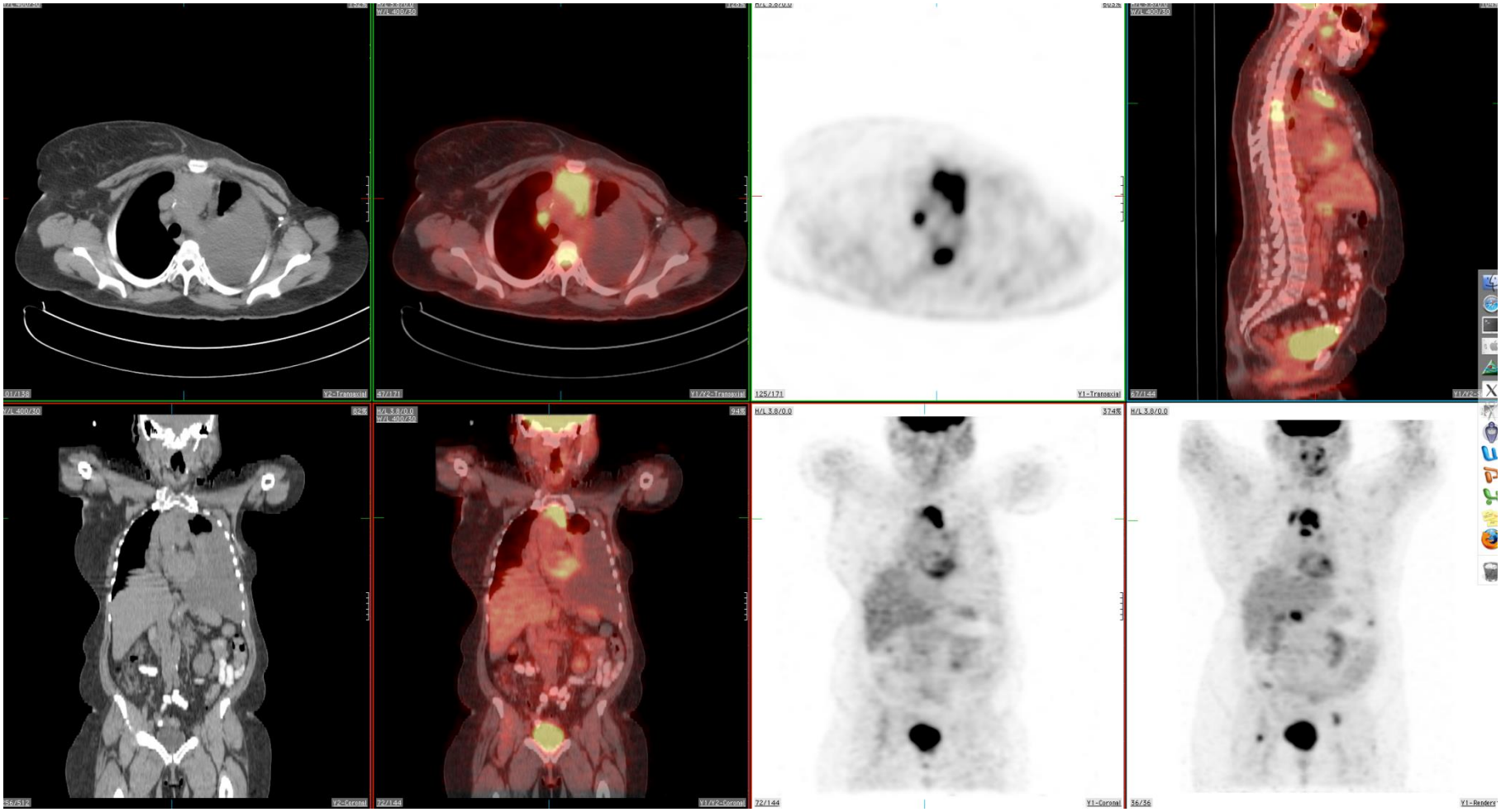


CT Image



Discovery™ LS

Mediastinal and spine metastases (breast)

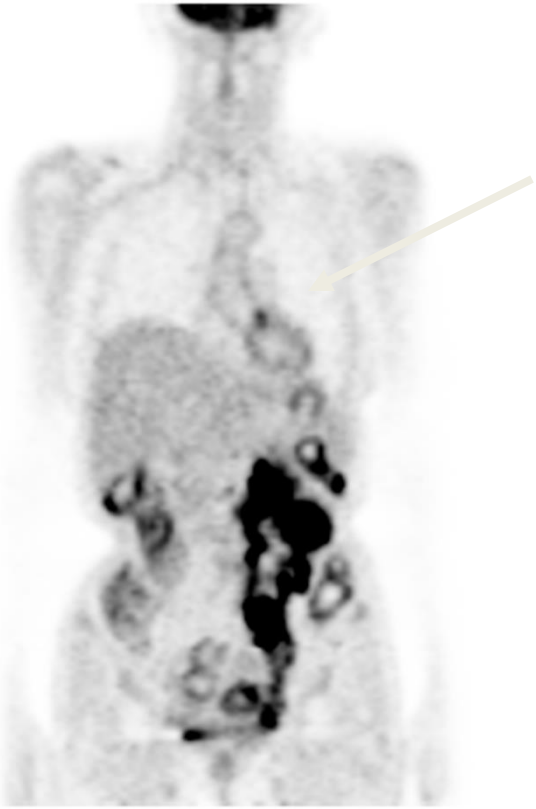


Metastatic Breast Cancer

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

Non-attenuation corrected



Attenuation corrected

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**

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

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

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

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