Introduction to Medical Imaging

BME/EECS 516

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(edited by JF)

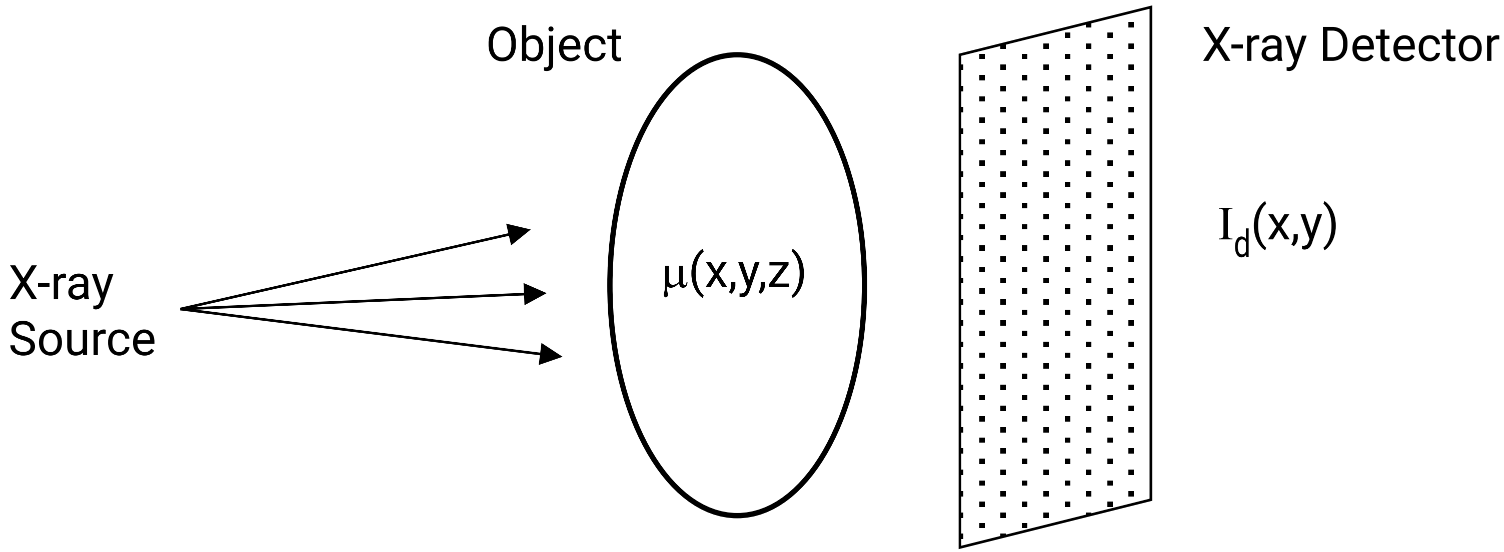
Medical Imaging

- Non-invasive visualization of internal organs, tissue, etc.
  - Is endoscopy an imaging modality?
- Image – a 2D signal $f(x,y)$ or 3D $f(x,y,z)$
  - Is a 1D non-imaging sensing techniques an imaging modality?

Major Modalities

- Projection X-ray (Radiography)
- X-ray Computed Tomography (CT)
- Nuclear Medicine (SPECT, PET)
- Ultrasound
- Magnetic Resonance Imaging

Projection X-ray Imaging

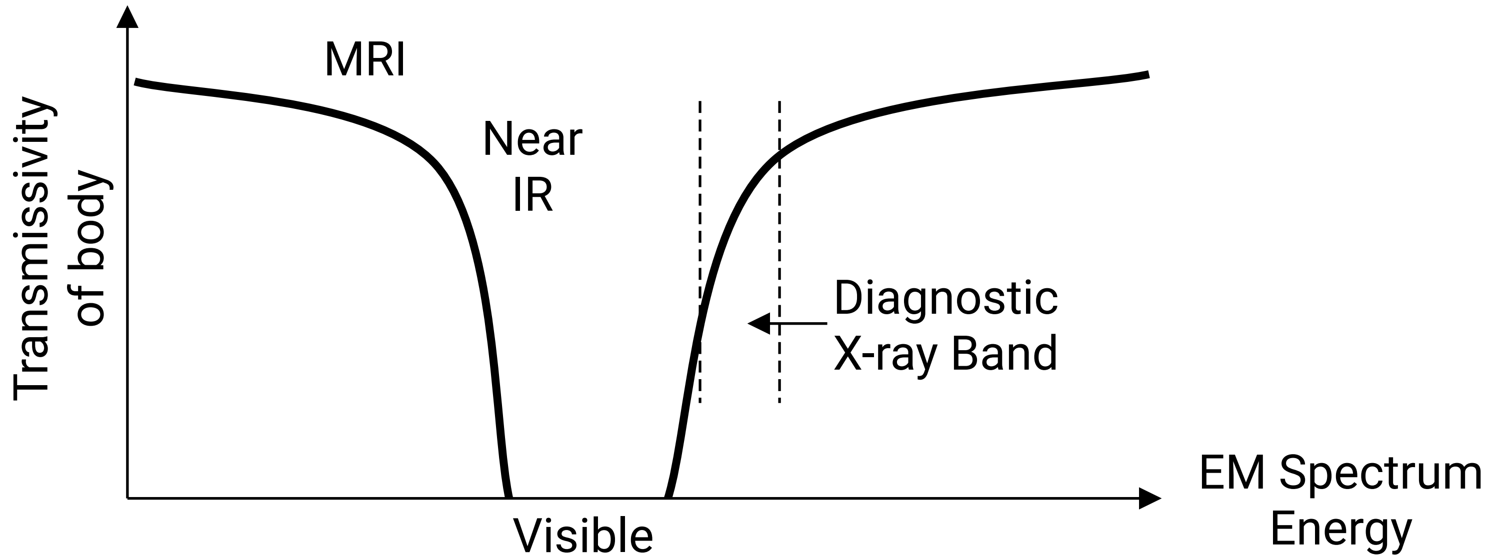


- Image records transmission of x-rays through object

- The integral is a line-integral or a "projection" through obj

- $\mu(x,y,z)$ – x-ray attenuation coefficient, a tissue property, a function of electron density, atomic #, …

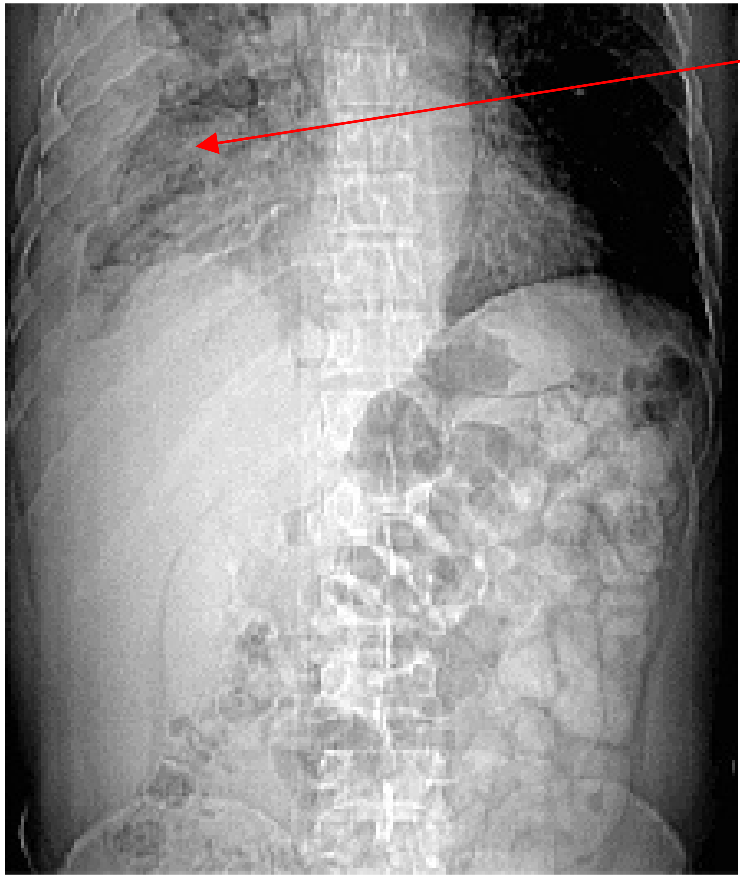
Projection X-ray Imaging



- X-ray imaging requires interactions of x-ray photons with object – work in a specific energy band
  - Above this band – body is too transparent
  - Below this band – body is too opaque
  - Well below this band – wavelengths are too long
- One problem with x-ray imaging: no depth (z) info

X-ray Imaging
Projection vs Tomographic

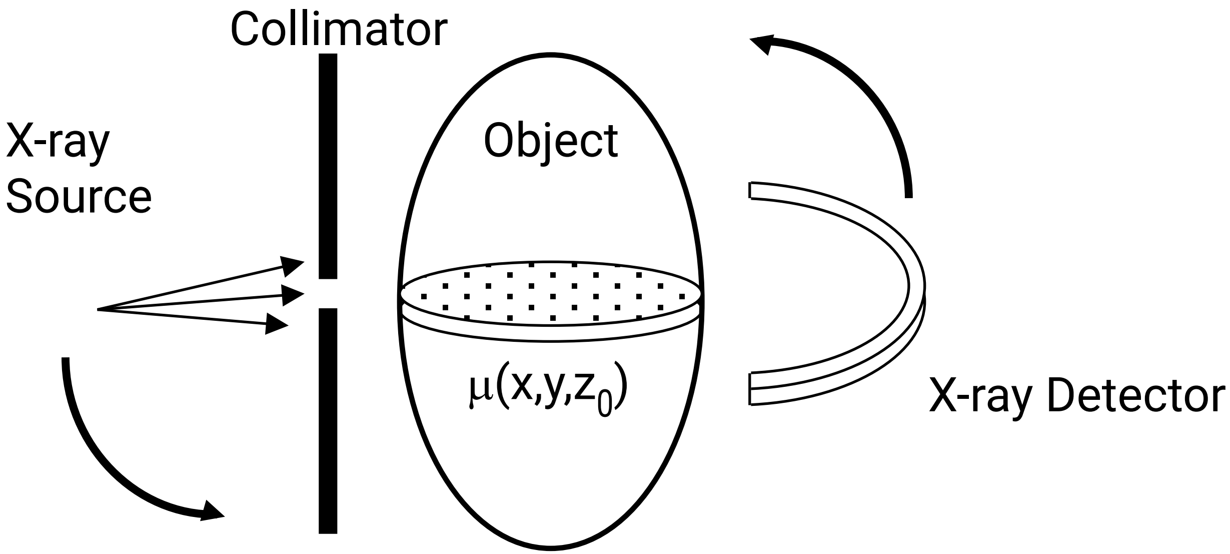
Chest
Mass



Projection Image

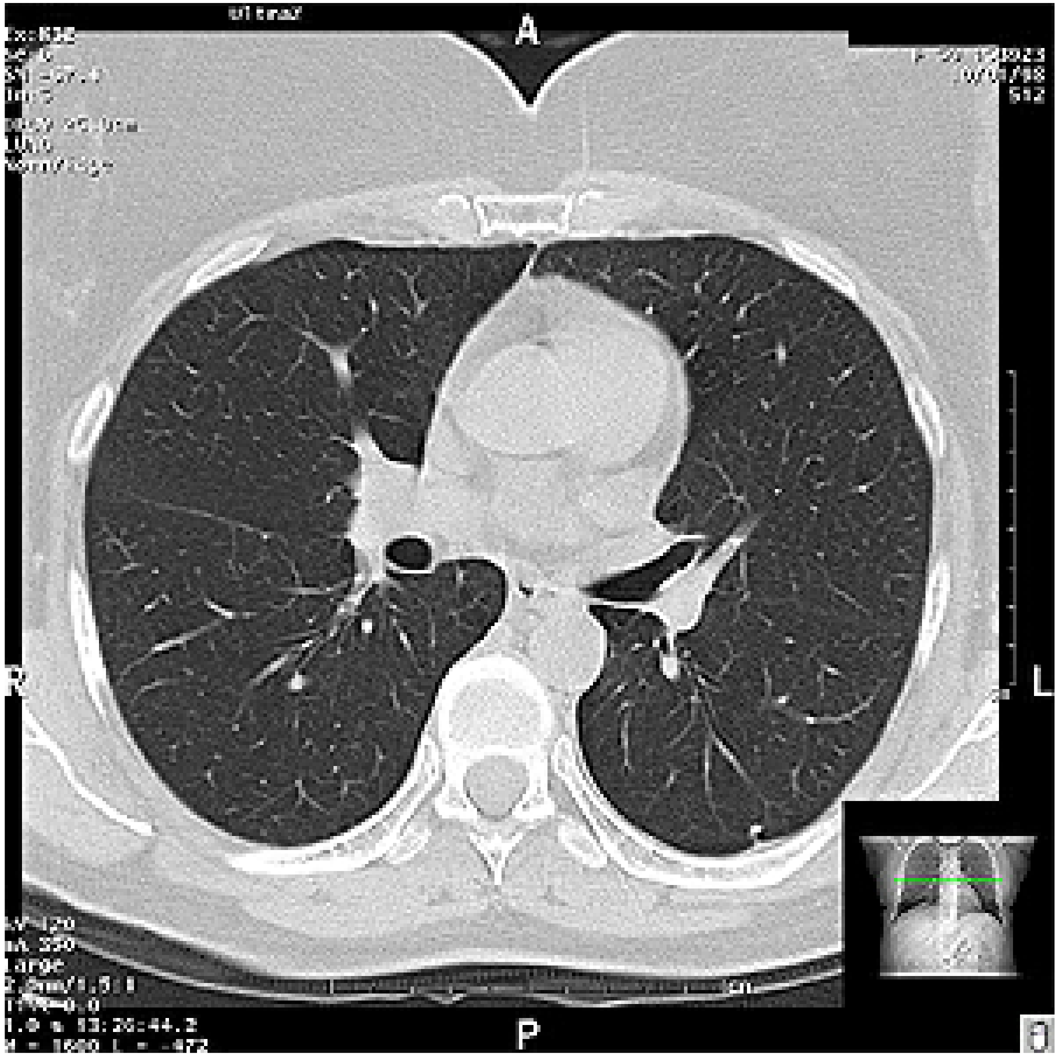
Cross-sectional Image

X-ray Computed Tomography

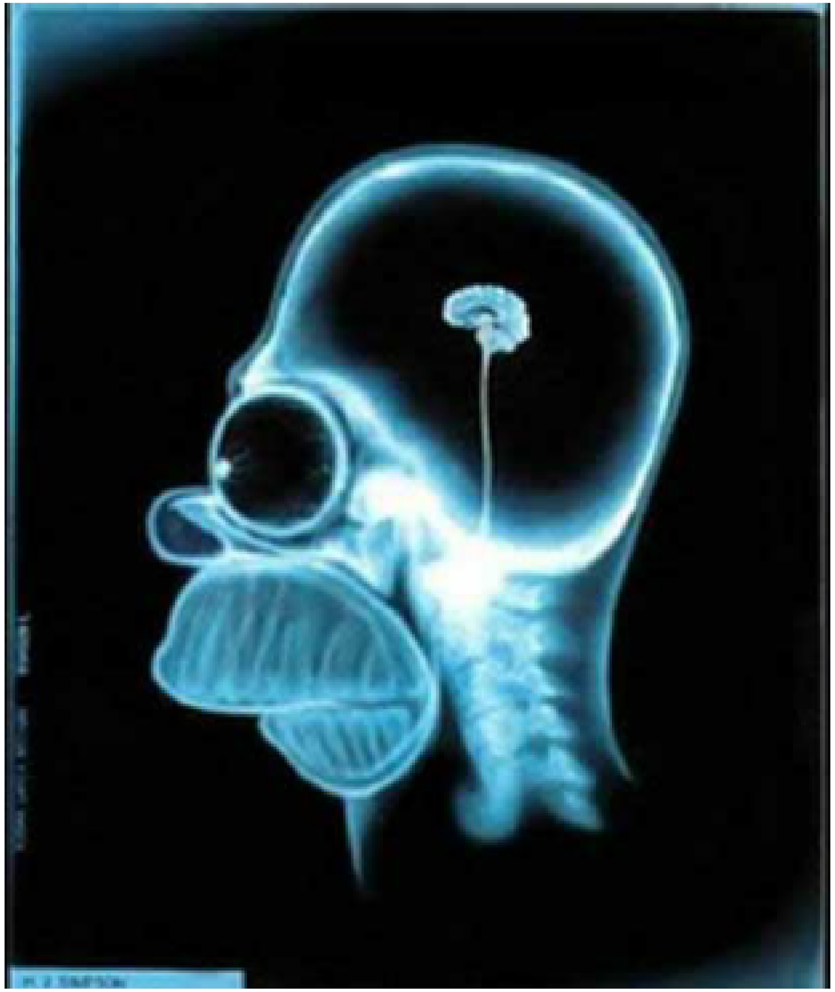


- Uses x-rays, but exposure is limited to a slice (or "a couple of" slices) by a collimator
- Source and detector rotate around object – projections from many angles
- The desired image, $I(x,y) = \mu(x,y,z_0)$, is computed from the projections

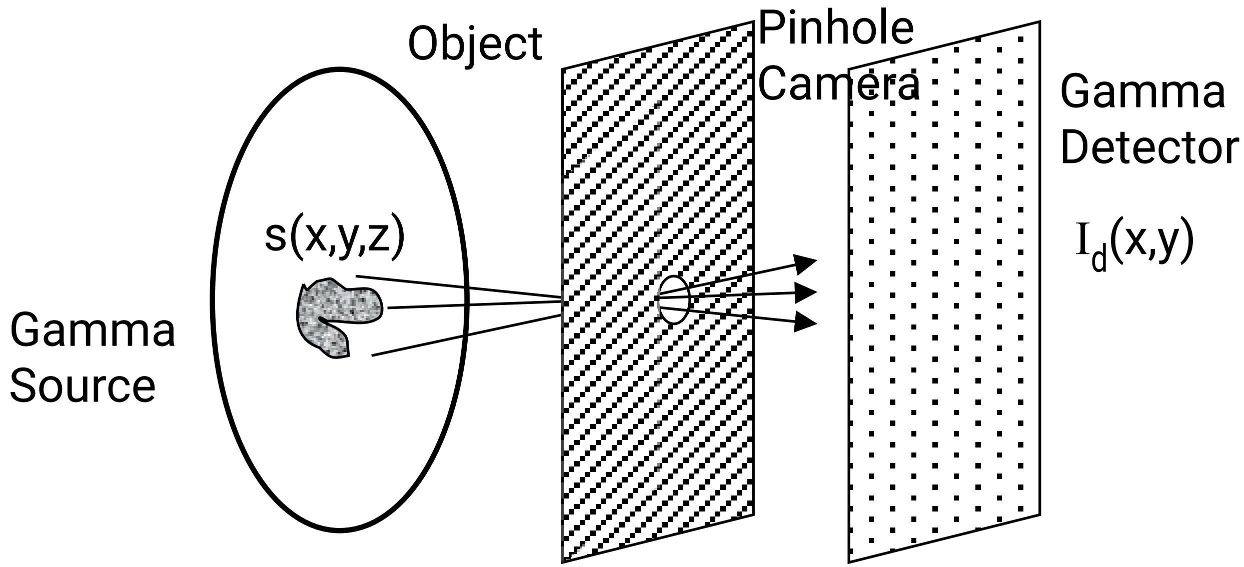
X-ray Computed Tomography



Anatomical vs Functional Imaging



Nuclear Medicine (Scintigraphy)



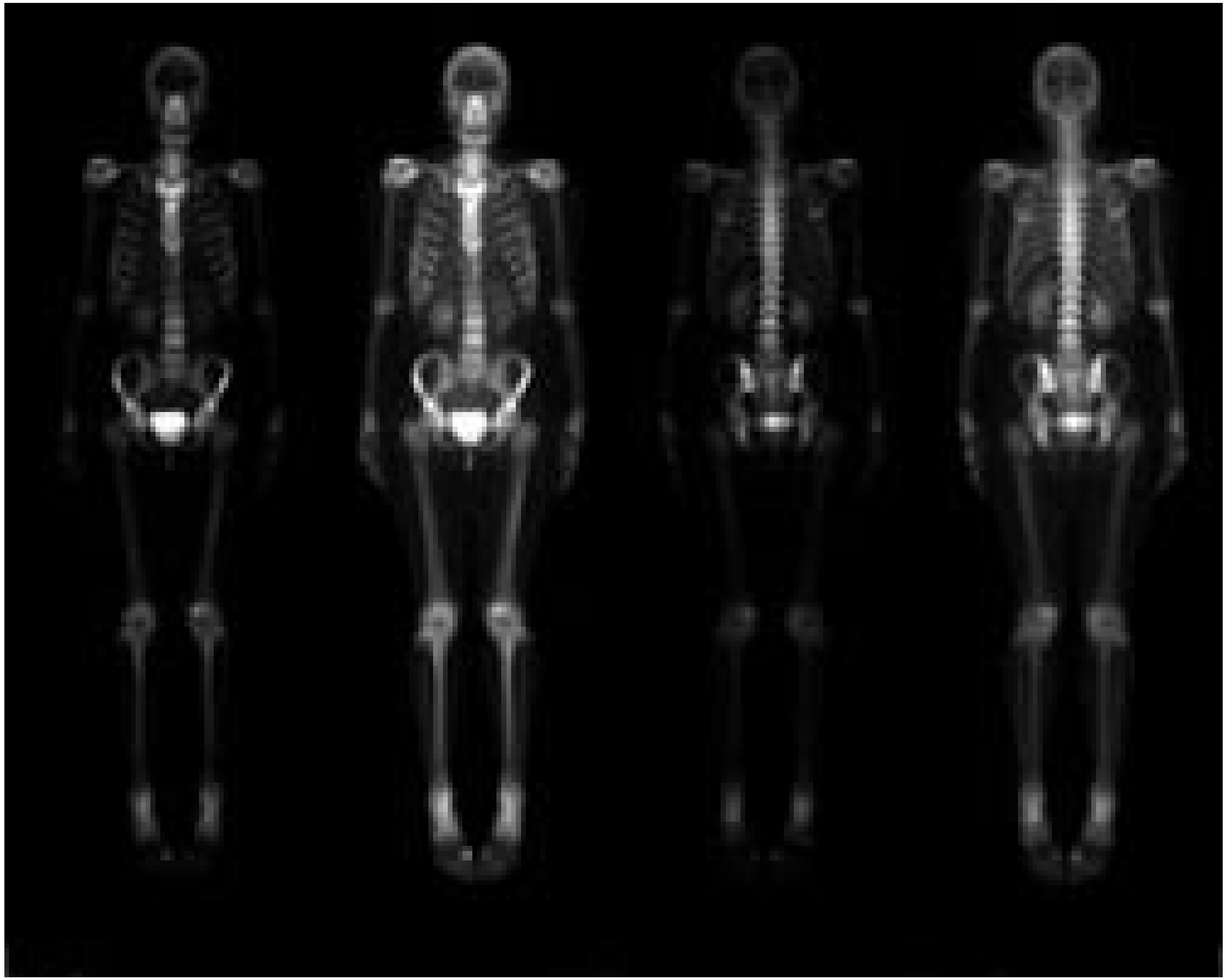
- Detector records *emission* of gamma photons from radioisotopes introduced into the body

- The integral is a line-integral or a "projection" through obj
- Source s(x,y,z) usually represents a selective uptake of a radio-labeled pharmaceutical

Nuclear Medicine (Scintigraphy)

- Issue: Pinhole Size
  - Large pinhole – more photons, better SNR
  - Large pinhole – more blur, reduced resolution
- Issue: Half-life
  - Long half lives are easier to handle, but continue to irradiate patient after imaging is done
- Issue: Functional Specificity
  - Pharmaceuticals must be specific to function of interest
  - E.g. Thallium, Technicium
- Issue: No depth info
  - Nuclear Medicine Computed Tomography (SPECT, PET)

Nuclear Medicine (Scintigraphy)



Bone Scan

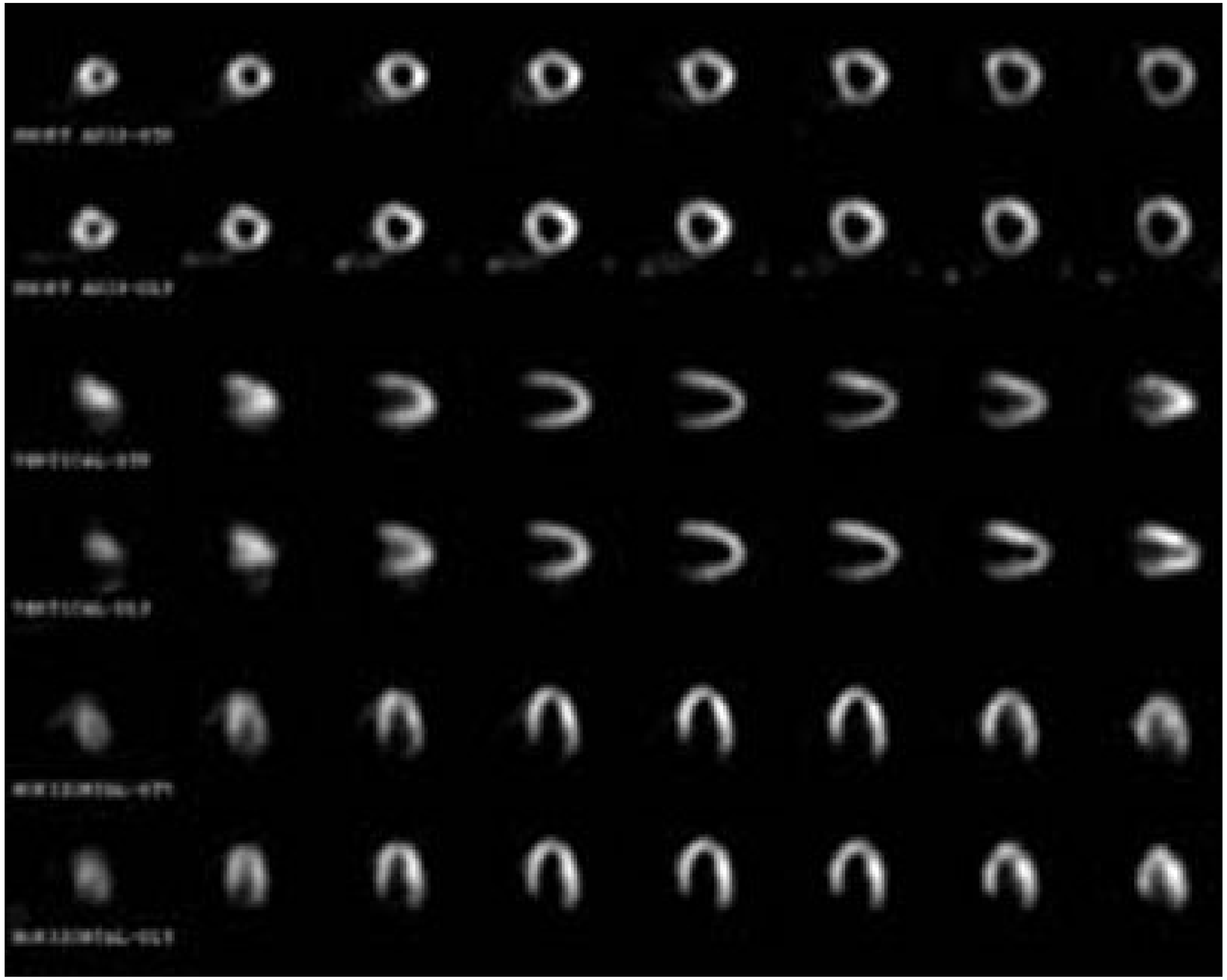
SPECT Scanner (3 heads)

Nuclear Medicine (SPECT)

Short Axis

Long Axis

Long Axis



Cardiac (Left Ventricle) Perfusion Scan

PET Scanner

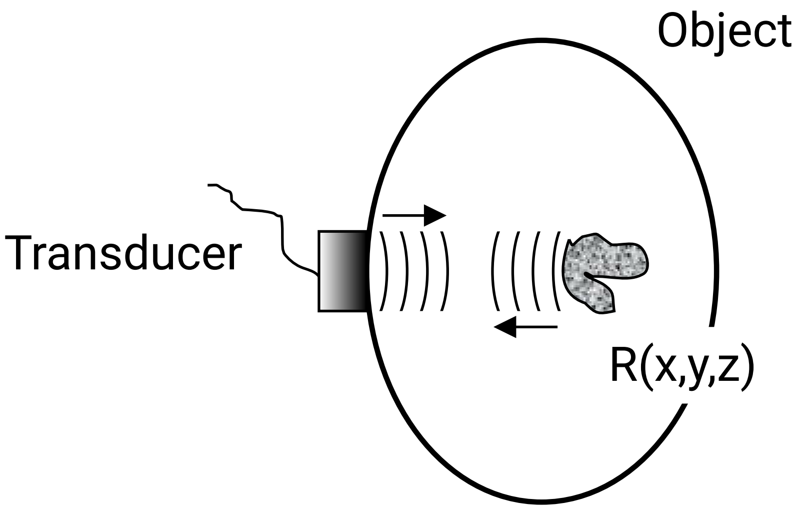
http://upload.wikimedia.org/wikibooks/en/f/fb/PetDiag2.jpg

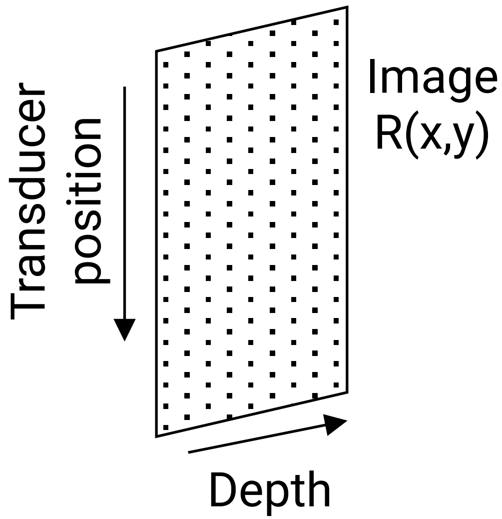
PET-CT Scanner

PET-CT Scan

Anatomy | Function | Both

Ultrasound Imaging





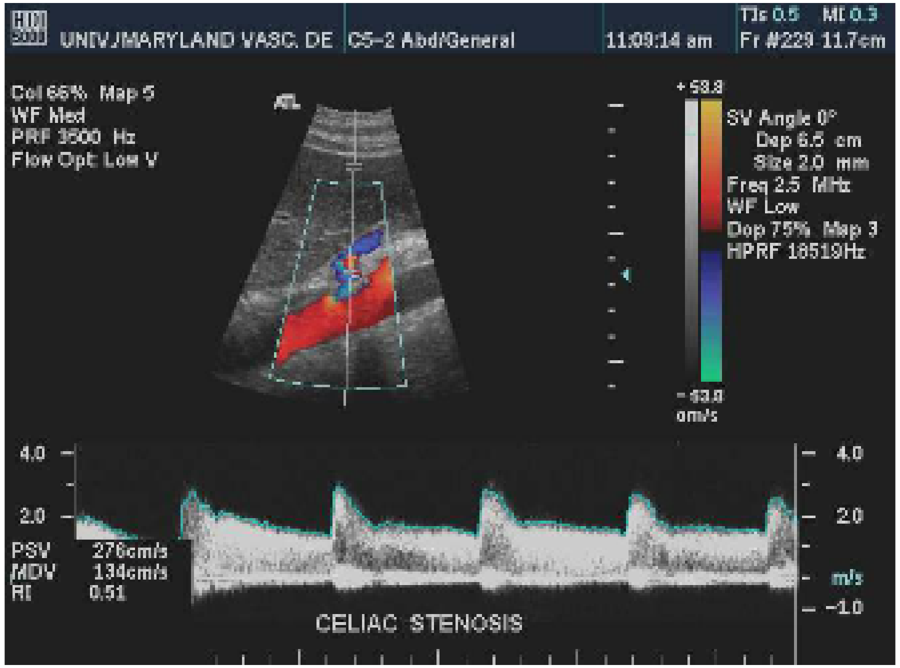
- Image reflectivity of acoustic wave, R(x,y,z).
- Depth – A function of time (ping-echo)
- Lateral – Focusing of wavefronts
- Direct imaging (e.g. vs. computed) modality – echo data is placed directly into image matrix

Ultrasound Imaging

- Issue: Transmit Frequency
  - Increase in frequency reduces wavelength:
  - Reduced (improved) resolution size (2-3 λ)
  - Also improved lateral resolution (diffraction):
  - Increases attenuation (and thus, range of depth)
- Issue: Flow
  - Can use Doppler effect to image flow
- Issue: Speckle
  - Most noise in US is speckle (signal dependent)

Ultrasound Imaging

High-Resolution



Color Doppler

Magnetic Resonance Imaging

- Atomic nuclei and hydrogen nuclei, ^1H, in particular, have a magnetic moment
  - Moments tend to become aligned to applied field
  - Creates magnetization, m(x,y,z) (a tissue property)
- MRI makes images of m(x,y,z)

Magnetic Resonance Imaging

RF Excitation
(Energy into tissue)

Magnetic fields
are emitted

- The magnetization is excited into an observable state
- Magnetization emits energy at a resonant frequency:

$$\omega = \lambda B$$

(63 MHz at 1.5 T)

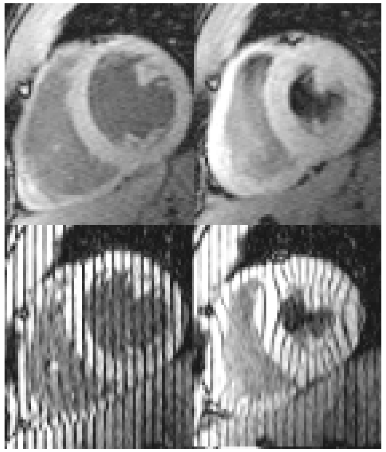
Magnetic Resonance Imaging

- Frequency is proportional to magnetic field
  - We can create a frequency vs. space variation:

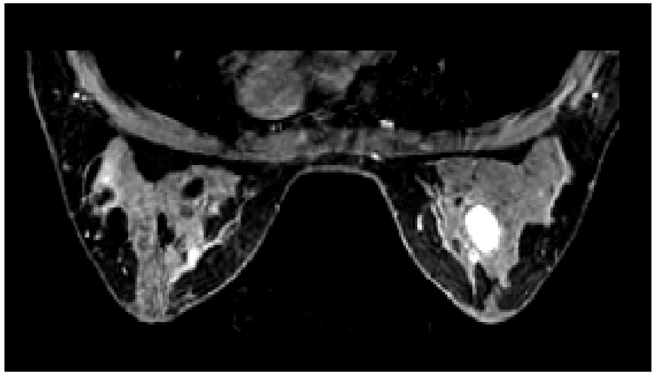
$$\omega(x,y,z) = \lambda \, B(x,y,z)$$

  - Use Fourier analysis to determine spatial location
- Interestingly, λ is much larger than resolution – not imaging EM direction, but using its frequency

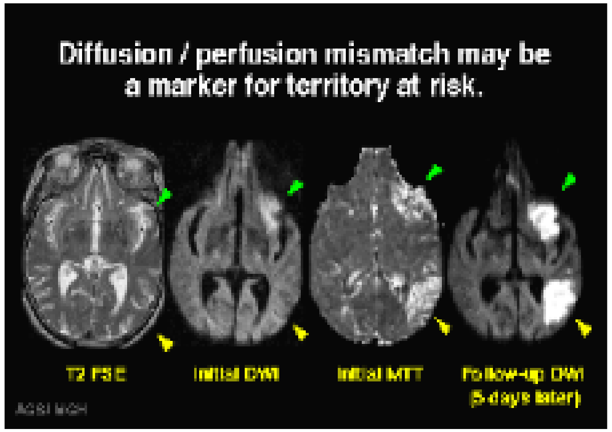
MRI



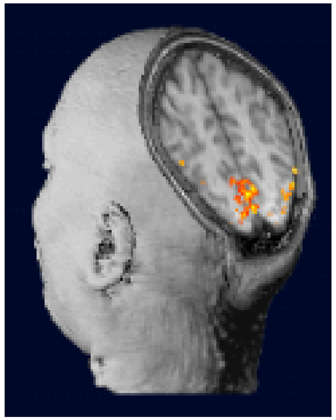
cardiac



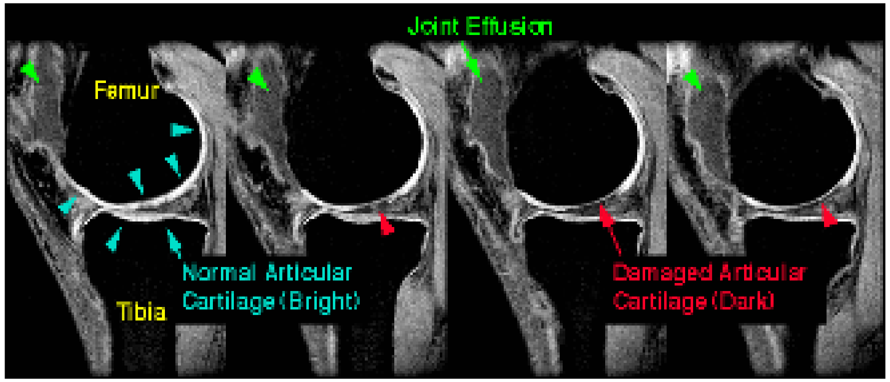
cancer



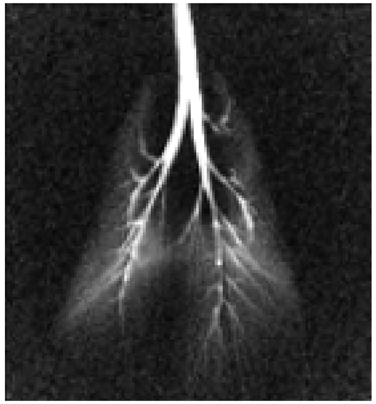
stroke



neuro function



joint



lung