

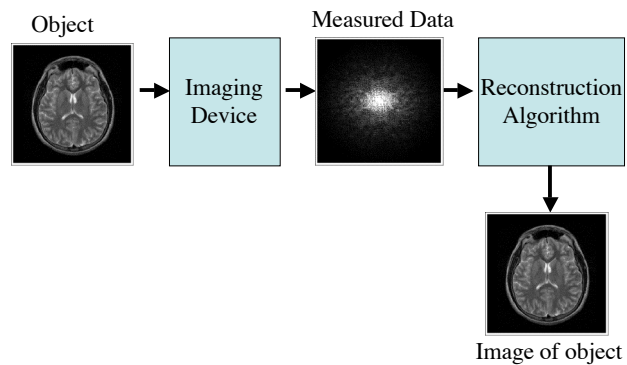
Bioengineering 280A  
Principles of  
Biomedical Imaging

Fall Quarter 2007  
Lecture 1

## Goals of the Course

1. Develop a firm understanding of the fundamentals of medical imaging, including an appreciation for the common principles underlying the various modalities.
2. Gain a basic understanding of the physical principles underlying the major modalities, including X-ray, computed tomography, MRI, and ultrasound.

## Basic Imaging



## Brief History of Medical Imaging

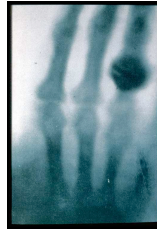
- 1895 - Roentgen discovers X-rays
- 1942 - Dussik demonstrates transmission ultrasound in the brain.
- 1946 - Bloch and Purcell discover nuclear magnetic resonance (NMR)
- 1972 - Hounsfield develops the first computed tomography scanner.
- 1973 - Lauterbur invents magnetic resonance imaging (MRI)
- 1974 - Ledley develops the first whole body CT scanner.

## X-Rays

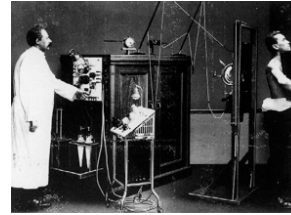


8 November 1895, Wilhelm Conrad Roentgen discovers X-rays. Receives first Nobel Prize in Physics in 1901.

22 November 1895 X-ray of Mrs. Roentgen's hand.



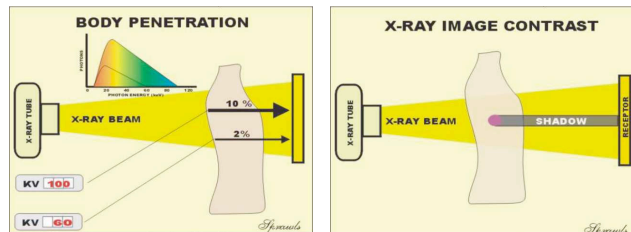
## X-Ray



An early X-ray imaging system



## X-Ray



## Computed Tomography

1917 Johann Radon establishes the mathematical framework for tomography, now called the Radon transform.



1963. Allan Cormack publishes mathematical analysis of tomographic image reconstruction. Is unaware of Radon's work.

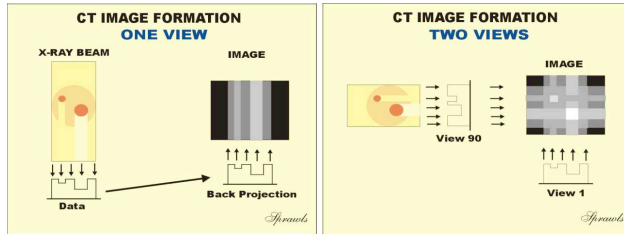


1972 Godfrey Hounsfield develops first CT system. Unaware of either Radon or Cormack's work, develops his own reconstruction method.



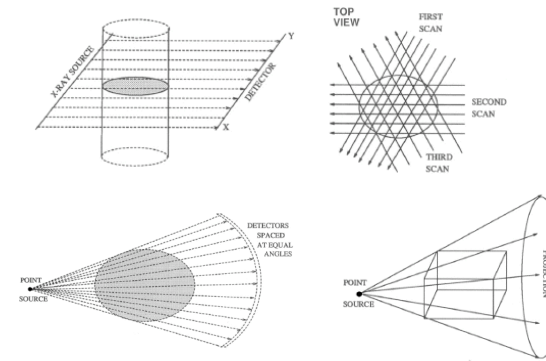
1979 Hounsfield and Cormack receive the Nobel Prize in Physiology or Medicine.

# Computed Tomography



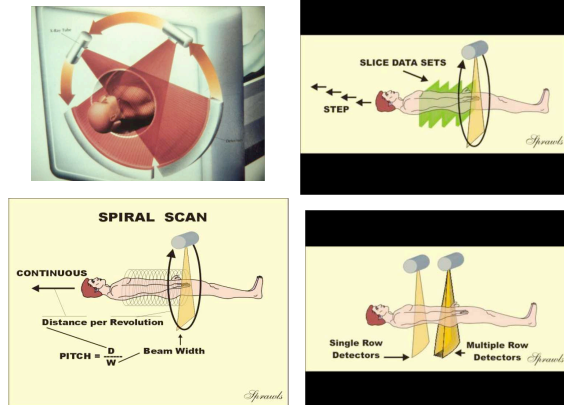
From <http://www.sprawl.org/resources/CTIMG/classroom.htm>

# Computed Tomography



From [http://www.sv.vt.edu/xray\\_ct/parallel/Parallel\\_CT.html](http://www.sv.vt.edu/xray_ct/parallel/Parallel_CT.html)

# Computed Tomography



From <http://www.sprawl.org/resources/CTIMG/classroom.htm>

# Computed Tomography

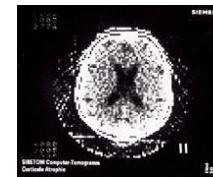
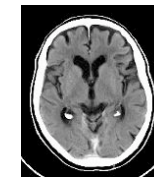


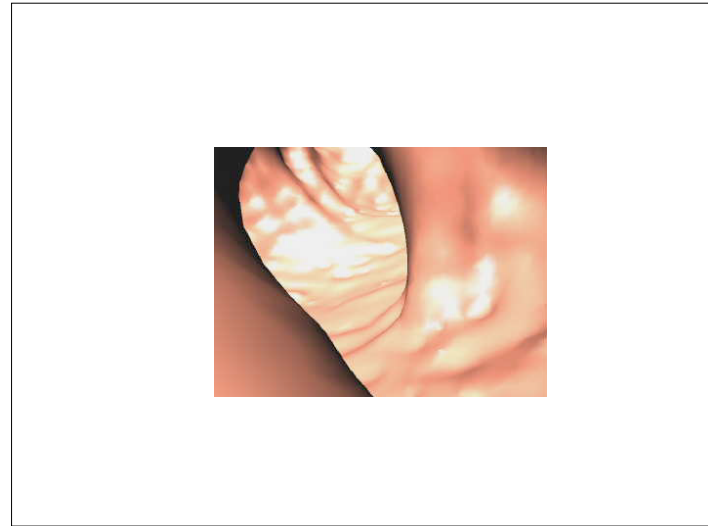
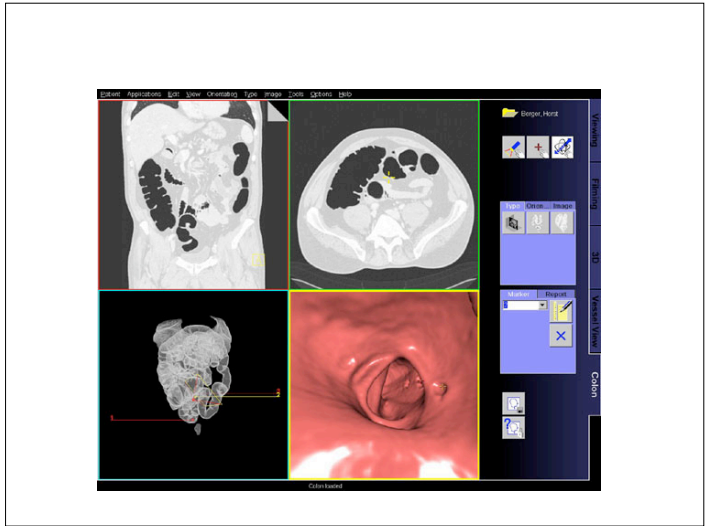
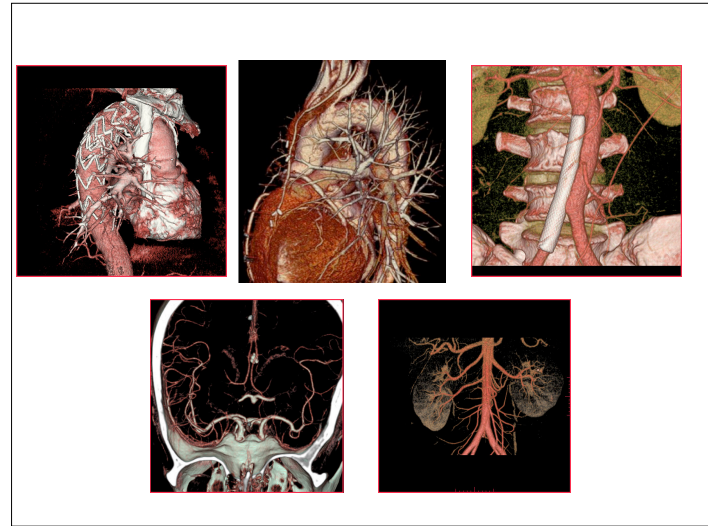
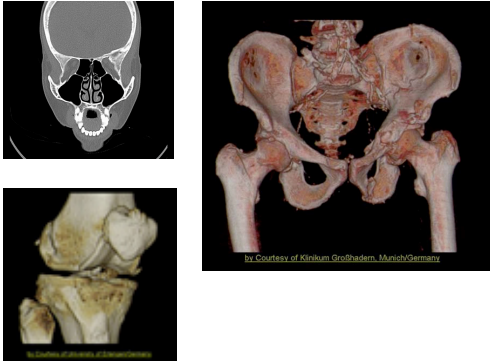
Image from Siemens Siretom CT scanner, circa 1975. 128x128 matrix.



Modern CT image acquired with a Siemens scanner. 512x512 matrix.



# Computed Tomography

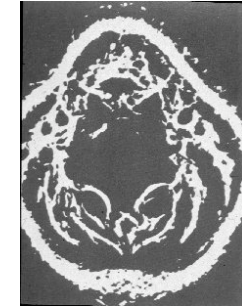
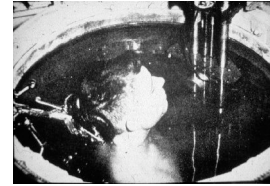


## History of Ultrasound



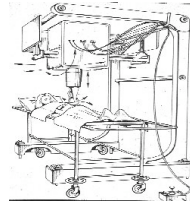
1942 Dr. Karl Theodore Dussik  
Transmission ultrasound  
investigation of the brain  
First published work on medical  
ultrasonics.

## History of Ultrasound

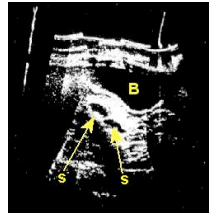


Holmes and Howry, 1955  
Subject submerged in water tank  
to achieve good acoustic coupling.  
Image of normal neck.

## History of Ultrasound



Automatic scanner, Glasgow, ca  
1959. Image shows twin gestation  
sacs (s) and bladder (B).



## Ultrasound Systems



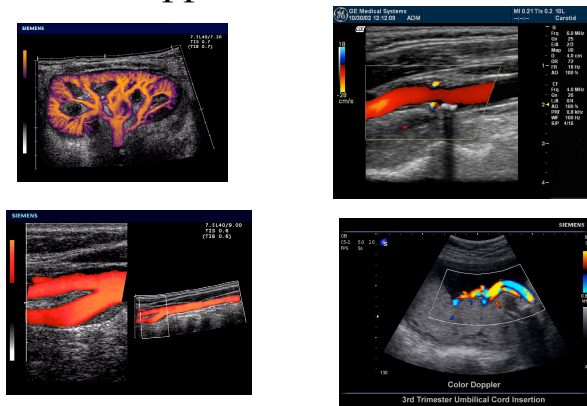
Acuson Sequoia



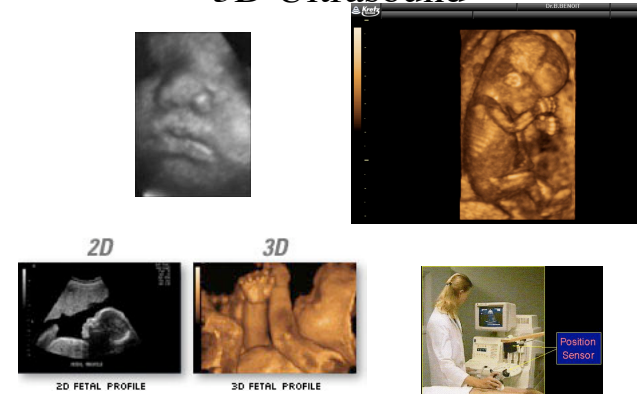
Sonosite 180



## Doppler Ultrasound



## 3D Ultrasound



## History of MRI



1946: Felix Bloch (Stanford) and Edward Purcell (Harvard) demonstrate nuclear magnetic resonance (NMR)



1973: Paul Lauterbur (SUNY) published first MRI image in Nature.

## History of MRI

Late 1970's: First human MRI images

Early 1980's: First commercial MRI systems

1993: functional MRI in humans demonstrated

## Clinical MRI System



## 3 Tesla Magnet at UCSD



## MRI System Block Diagram

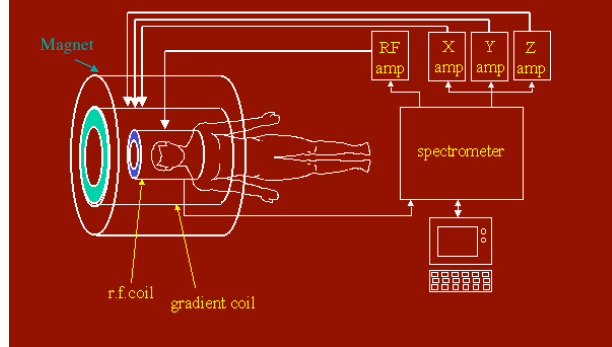
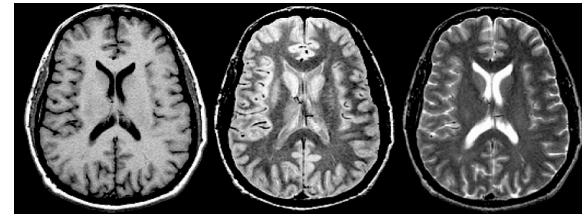


Image from <http://www.fmrib.ox.ac.uk/~stuart/lectures/lecture1/>

## Image Contrast



T<sub>1</sub>-weighted

Density-weighted

T<sub>2</sub>-weighted

Image from Rick Buxton

## MR Angiography

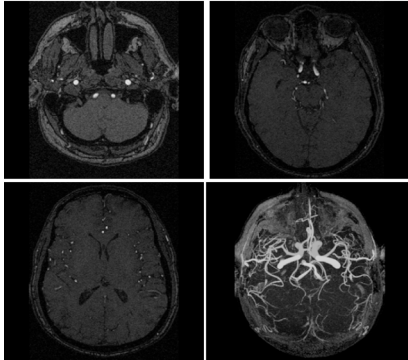


Image from R. Buxton

## Perfusion Imaging with Contrast

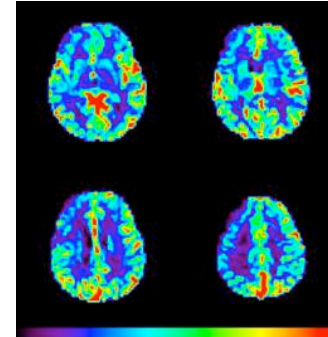


Image from [http://irc.chmcc.org/PowerPoint\\_HTMLpMRI/moyamoya\\_files/frame.htm](http://irc.chmcc.org/PowerPoint_HTMLpMRI/moyamoya_files/frame.htm)

## Perfusion Imaging with ASL

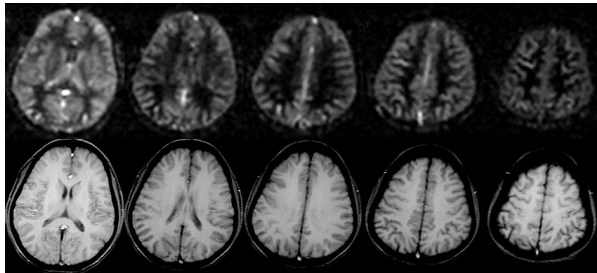


Image from E.C. Wong

## Cardiac Imaging



Image from <http://www.bidmc.harvard.edu/cmri/smash/smash.html>



## Cardiac Tagging

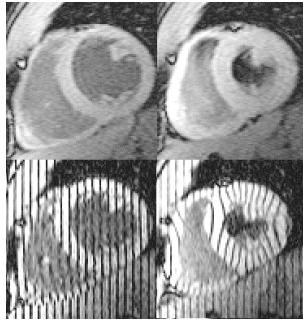


Image from <http://www.mri.jhu.edu/~cmveigh/LabIntro/tagging.html>

## Hyperpolarized Helium

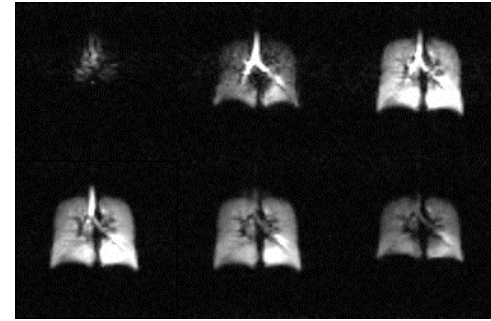


Image from <http://www.physics.utah.edu/~saam/#RES>

## Functional MRI

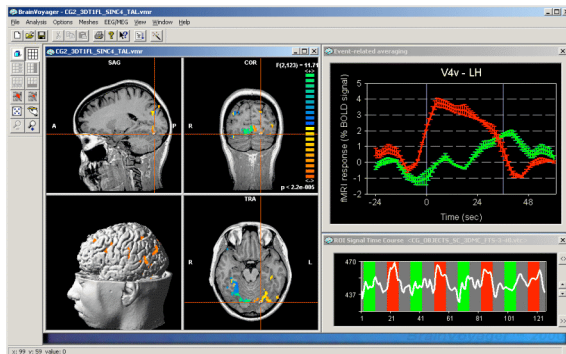


Image from <http://www.brainvoyager.de/>

## Diffusion Tensor Imaging

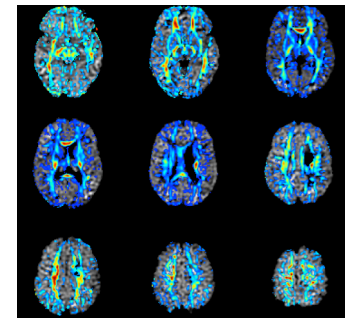


Image from L. Frank

## MR Microscopy

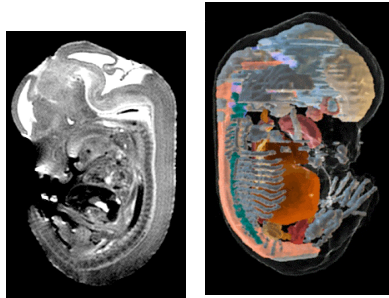


Image from <http://mouseatlas.caltech.edu/>

## MR Spectroscopy

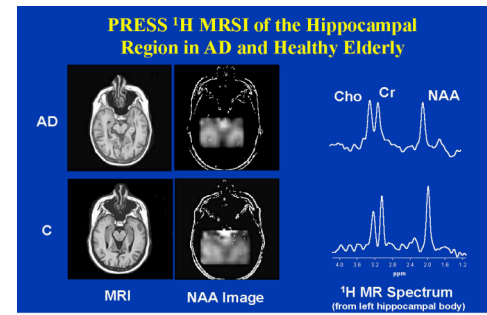
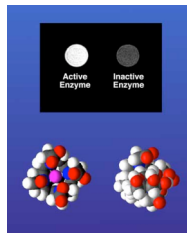


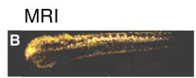
Image from <http://www.sj.med.va.gov/mrs/ad/result.htm>

## Molecular Imaging



EgadMe labels regions positive for beta-gal expression

Fluorescence (GFP)



Bright field

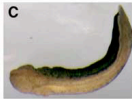


Image from <http://quad.bic.caltech.edu/~meadegroup/smart%20contrast%20agents.htm>