

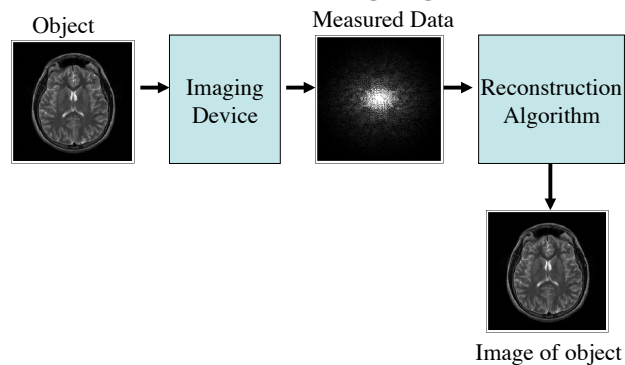
Bioengineering 280A  
Principles of  
Biomedical Imaging

Fall Quarter 2009  
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

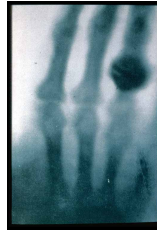
- 1895 - Roentgen discovers X-rays
- 1942 - Dussik demonstrates transmission ultrasound in the brain.
- 1946 - Bloch and Purcell discover nuclear magnetic resonance (NMR)
- 1972 - Hounsfield develops the first computed tomography scanner.
- 1973 - Lauterbur invents magnetic resonance imaging (MRI)
-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

## X-Rays

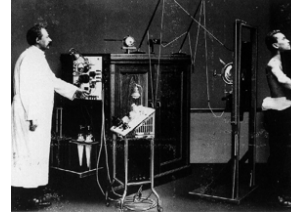


8 November 1895, Wilhelm Conrad Roentgen discovers X-rays. Receives first Nobel Prize in Physics in 1901.

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



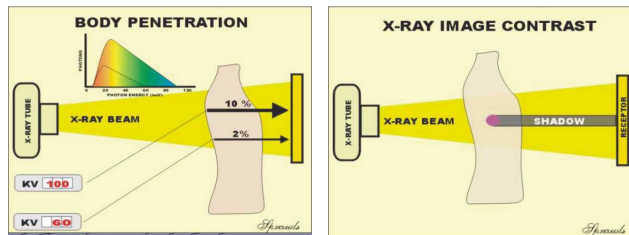
## X-Ray



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.

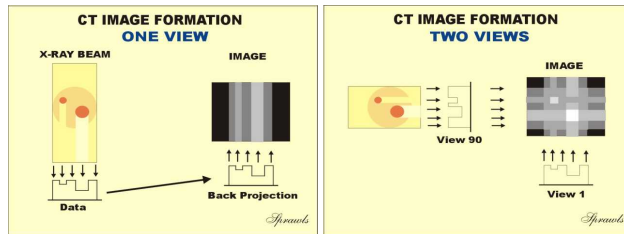


1972 Godfrey Hounsfield develops first CT system. Unaware of either Radon or Cormack's work, develops his own reconstruction method.



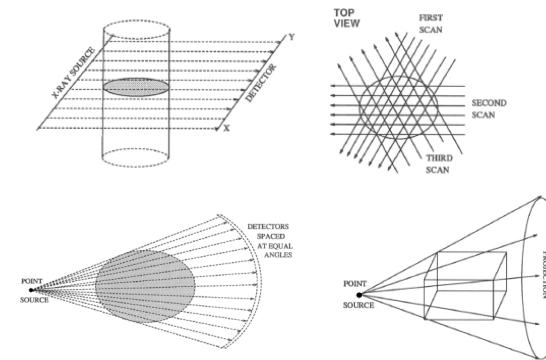
1979 Hounsfield and Cormack receive the Nobel Prize in Physiology or Medicine.

# Computed Tomography



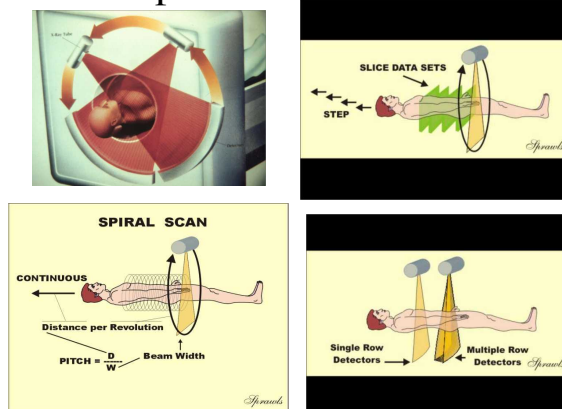
From <http://www.sprawls.org/resources/CTIMG/classroom.htm>

# Computed Tomography



From [http://www.sv.vt.edu/xray\\_ct/parallelParallel\\_CT.html](http://www.sv.vt.edu/xray_ct/parallelParallel_CT.html)

# Computed Tomography



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

# Computed Tomography

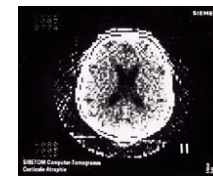
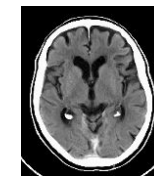


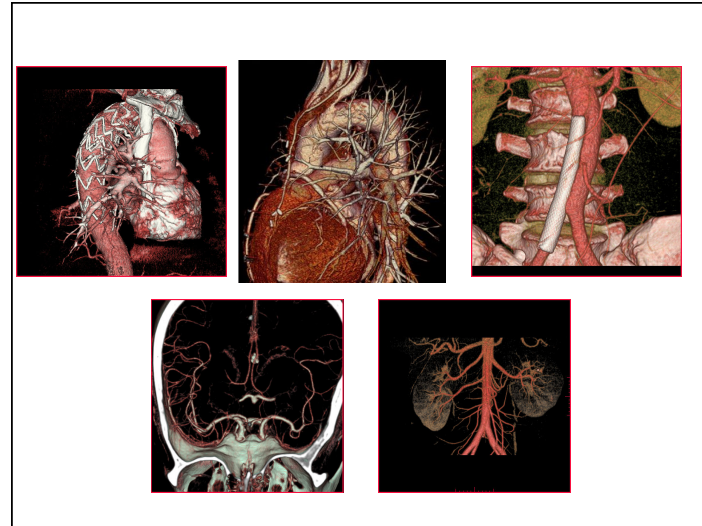
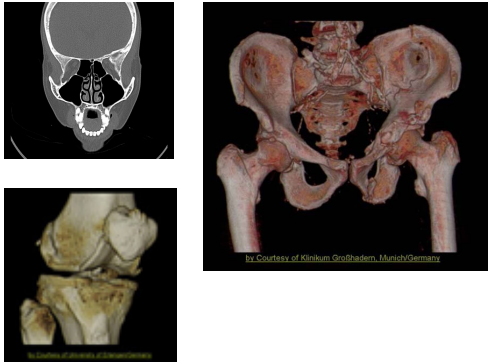
Image from Siemens Siretom CT scanner, circa 1975. 128x128 matrix.



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



## Computed Tomography



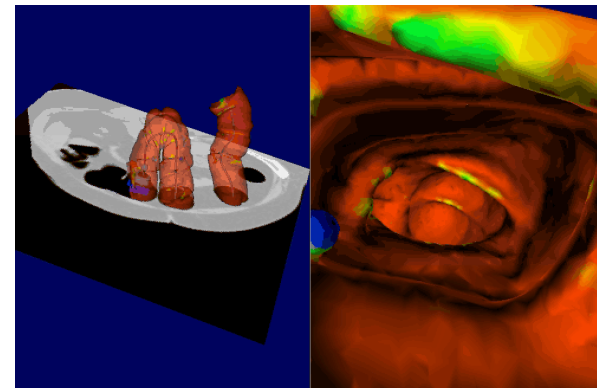
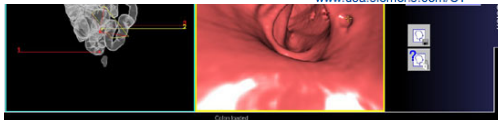
## Virtual Colonoscopy As Good As Other Colon Cancer Screening Methods, Study Finds

*ScienceDaily* (Sep. 23, 2008) — CT colonography (CTC), known as virtual colonoscopy, is as accurate at screening for colorectal cancers and pre-cancerous polyps as conventional colonoscopy, the current screening standard, according to the National CT Colonography Trial, a nationwide multi-center study that included the San Francisco VA Medical Center.

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**Do I Need a Colonoscopy?**  
Learn About Colonoscopies, Colon Cancer Risk Factors, and Prevention  
[www.TabletPrep.com](http://www.TabletPrep.com)

**Siemens Colonography**  
Non-Invasive Colonoscopies Using Advanced Technology From Siemens  
[www.usa.siemens.com/CT](http://www.usa.siemens.com/CT)



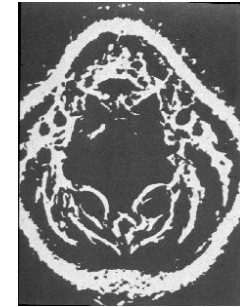
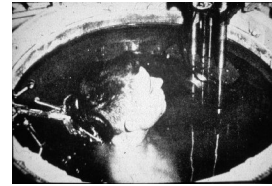


## History of Ultrasound



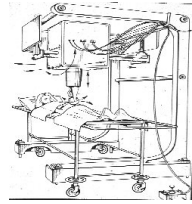
1942 Dr.Karl Theodore Dussik  
Transmission ultrasound  
investigation of the brain  
First published work on medical  
ultrasonics.

## History of Ultrasound

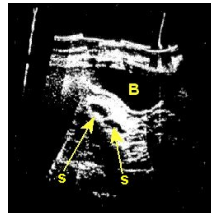


Holmes and Howry, 1955  
Subject submerged in water tank to  
achieve good acoustic coupling.  
Image of normal neck.

## History of Ultrasound



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



## Ultrasound Systems



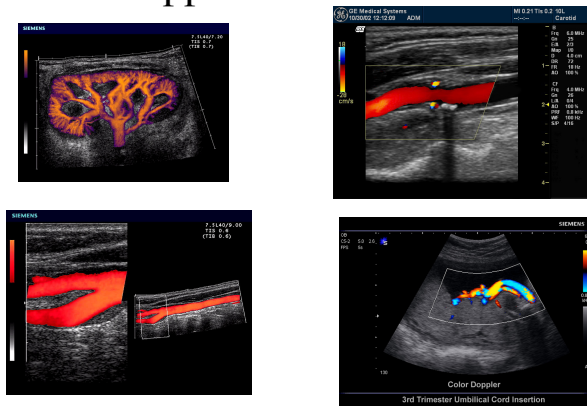
Acuson Sequoia



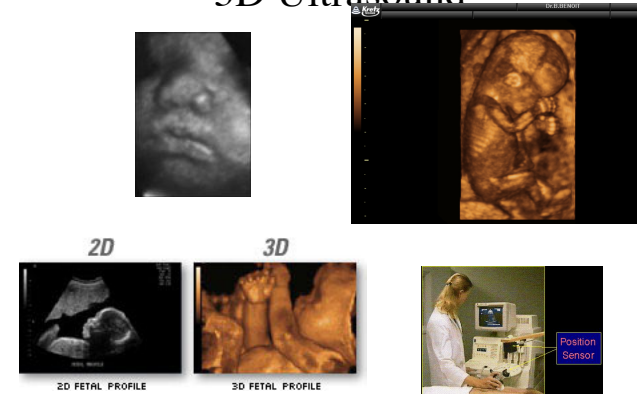
Sonosite 180



## Doppler Ultrasound



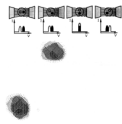
## 3D Ultrasound



## 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

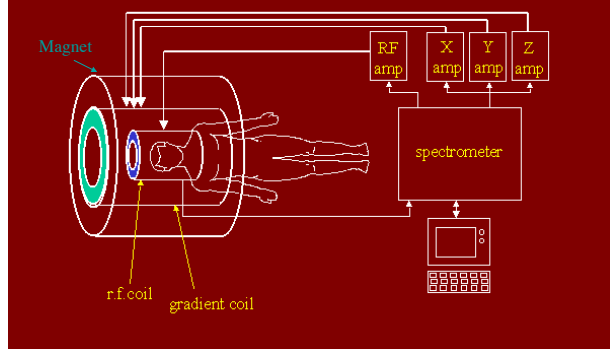
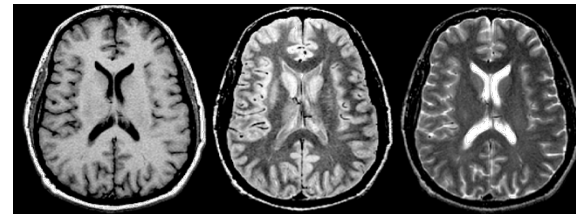


Image from <http://www.fmrib.ox.ac.uk/~stuart/lectures/lecture1/>

## Image Contrast



T<sub>1</sub>-weighted

Density-weighted

T<sub>2</sub>-weighted

Image from Rick Buxton

## MR Angiography

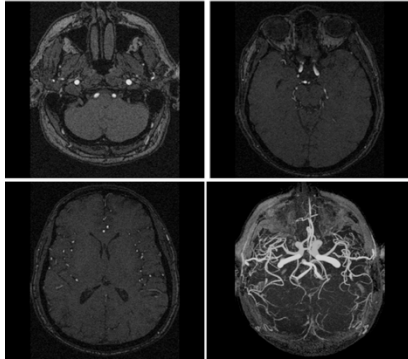


Image from R. Buxton

## Perfusion Imaging with ASL

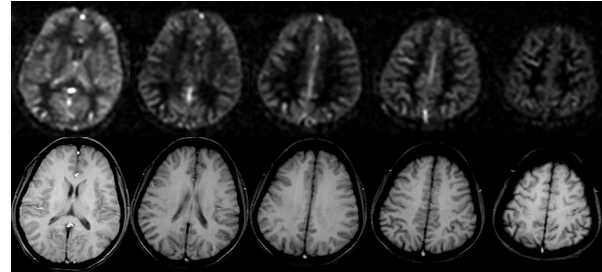


Image from E.C. Wong

## Cardiac Imaging

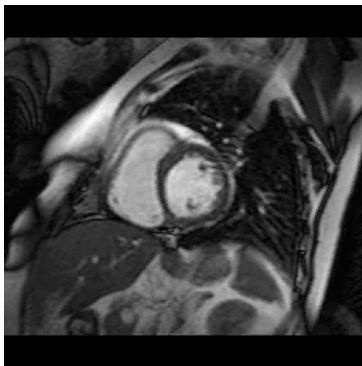


Image from <http://www.bidmc.harvard.edu/cm/slash/slash.html>

## Cardiac Tagging

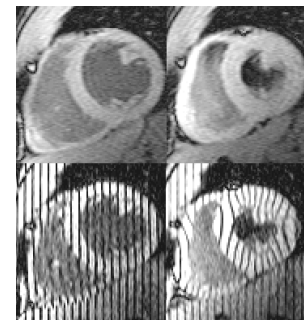


Image from <http://www.mri.jhu.edu/~emcveigh/Lab/Intrtagging.html>

## Functional MRI

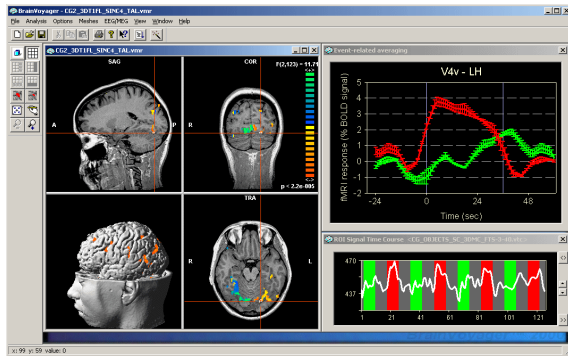


Image from <http://www.brainvoyager.de/>

## Diffusion Tensor Imaging

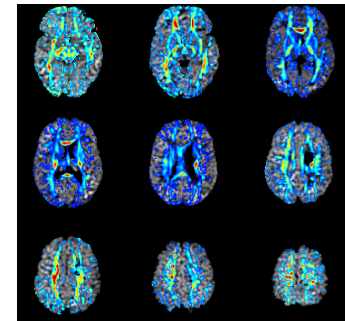


Image from L. Frank

## MR Microscopy

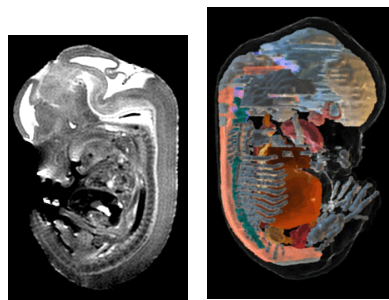


Image from <http://mouseatlas.caltech.edu/>

## MR Spectroscopy

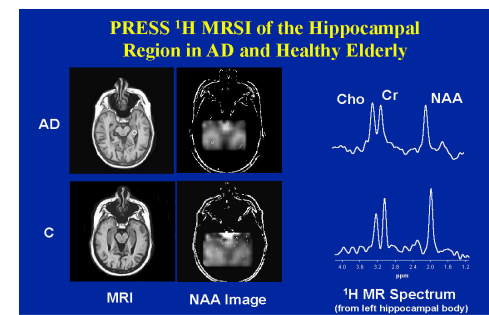
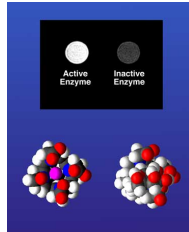


Image from <http://www.sf.med.va.gov/mrs/ad/result.htm>

# Molecular Imaging

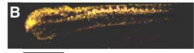


EgadMe labels regions positive for beta-gal expression

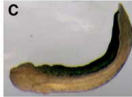
Fluorescence (GFP)



MRI



Bright field



(fixed and stained)

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