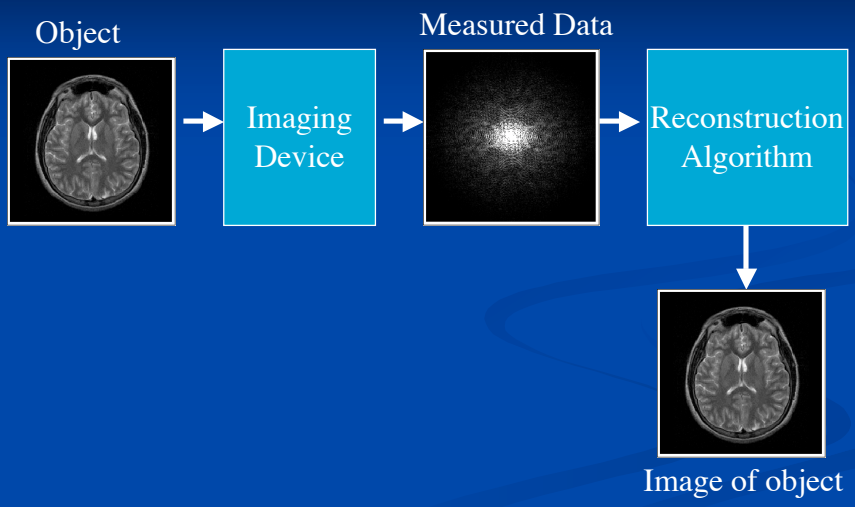
Bioengineering 280A Principles of Biomedical Imaging

Fall Quarter 2004 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

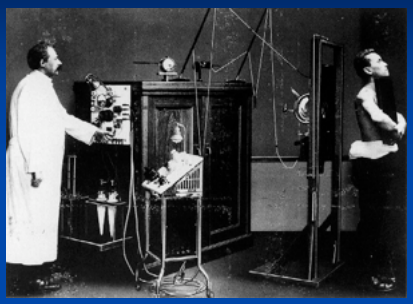
1895 - Roentgen discovers X-rays
1942 - Dussik demonstrates transmission ultrasound in the brain.
1946 - Bloch and Purcell discover nuclear magnetic resonance (NMR)
1972 - Hounsfield develops the first computed tomography scanner.
1973 - Lauterbur invents magnetic resonance imaging (MRI)
1974 - Ledley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

X-Rays

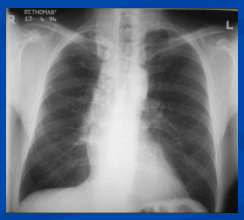
8 November 1895, Wilhelm Conrad Roentgen discovers X-rays. Receives first Nobel Prize in Physics in 1901.

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

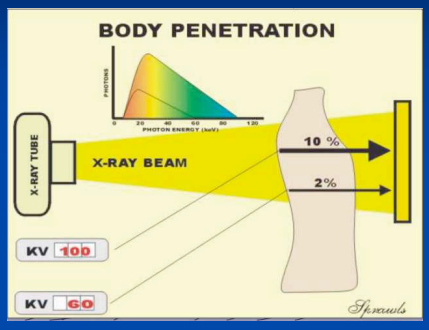
X-Ray

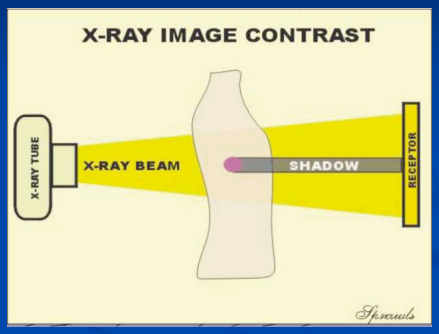


An early X-ray imaging system



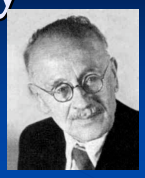
X-Ray



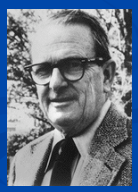


Computed Tomography

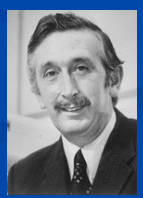
1917 Johann Radon establishes the mathematical framework for tomography, now called the Radon transform.



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

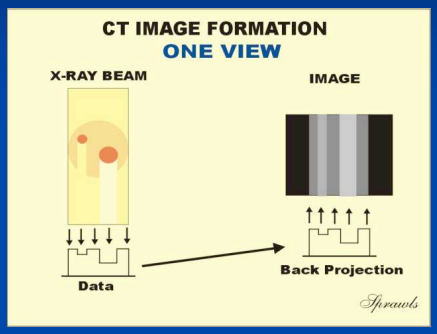


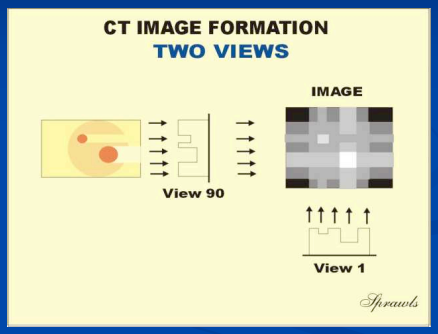
1972 Godfrey Hounsfield develops first CT system. Unaware of either Radon or Cormack's work, develops his own reconstruction method.



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

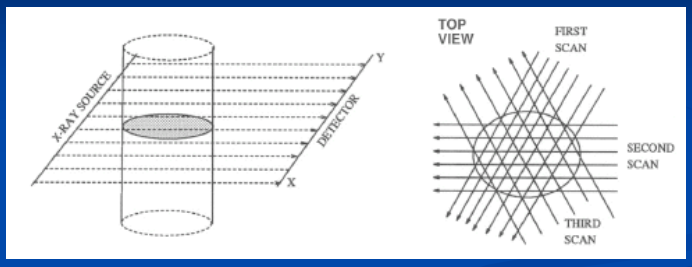
Computed Tomography

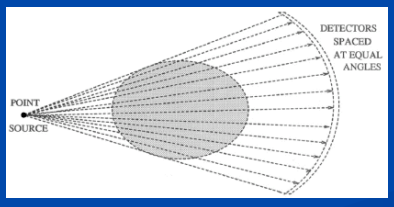


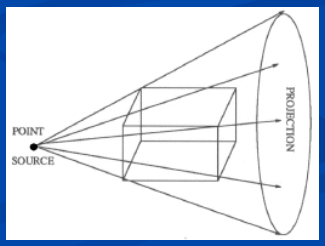


From http://www.sprawls.org/resources/CTIMG/classroom.htm

Computed Tomography

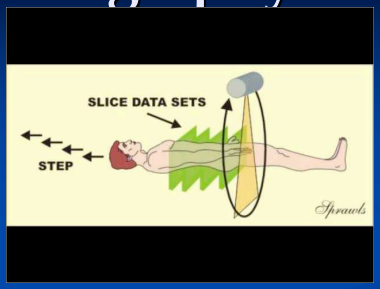


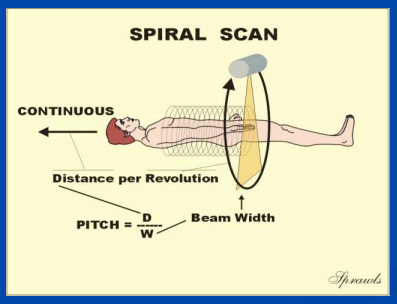


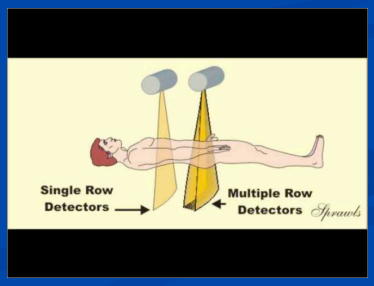


From http://www.sv.vt.edu/xray_ct/parallel/Parallel_CT.html

Computed Tomography







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

Computed Tomography

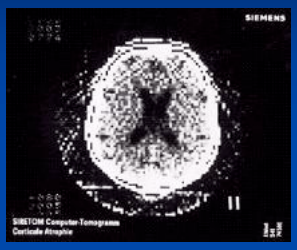

Image from Siemens Siretom CT scanner, circa 1975. 128x128 matrix.

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

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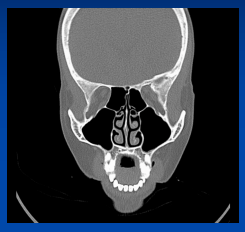
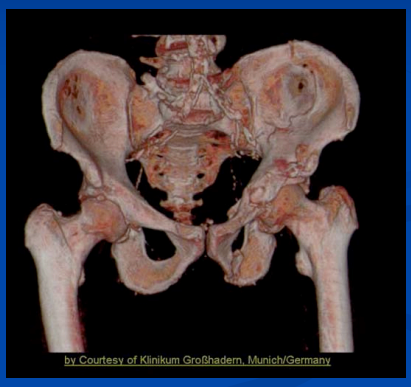
Computed Tomography





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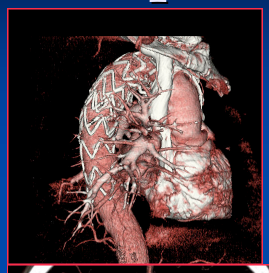
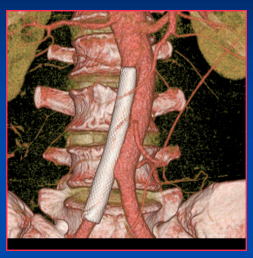
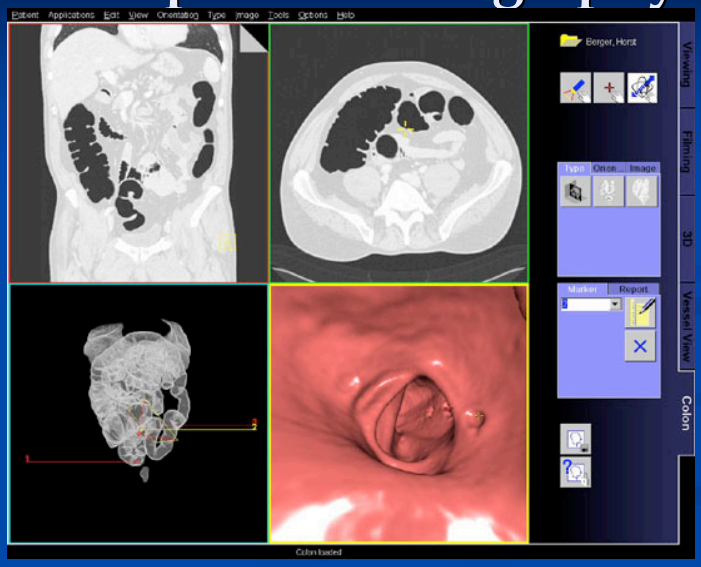
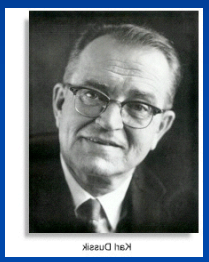




Computed Tomography



History of Ultrasound



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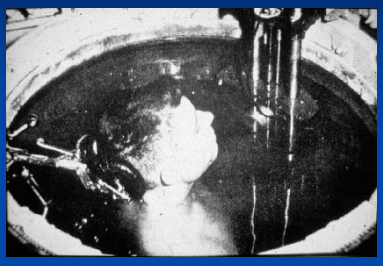
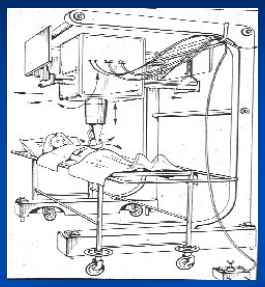
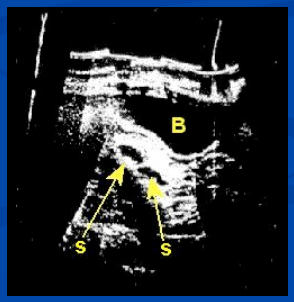
History of Ultrasound



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

History of Ultrasound



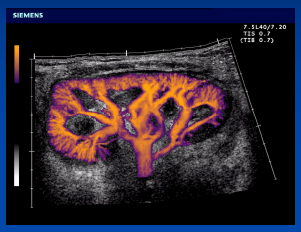


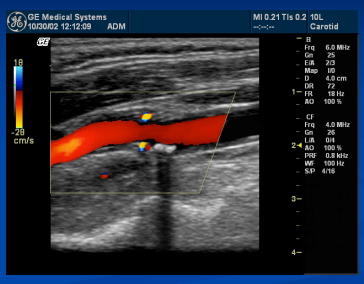
Automatic scanner, Glasgow, ca 1959. Image shows twin gestation sacs (s) and bladder (B).

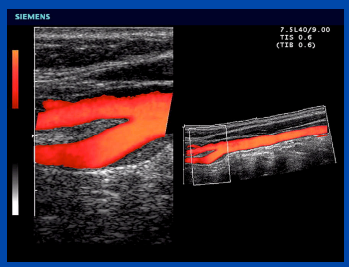
Ultrasound System

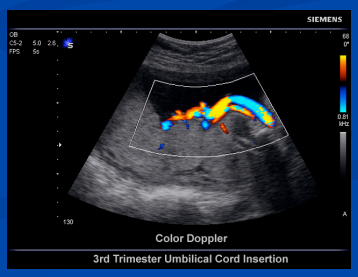
Acuson Sequoia

Doppler Ultrasound

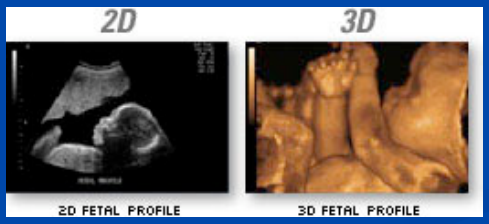




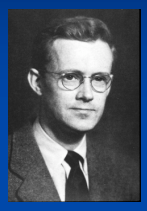




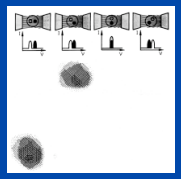
3D Ultrasound



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

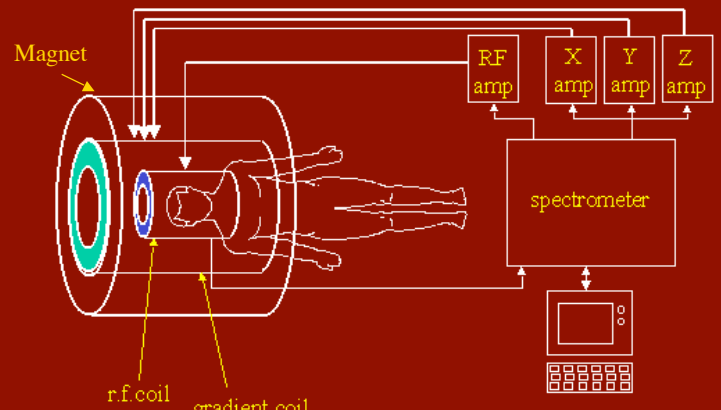
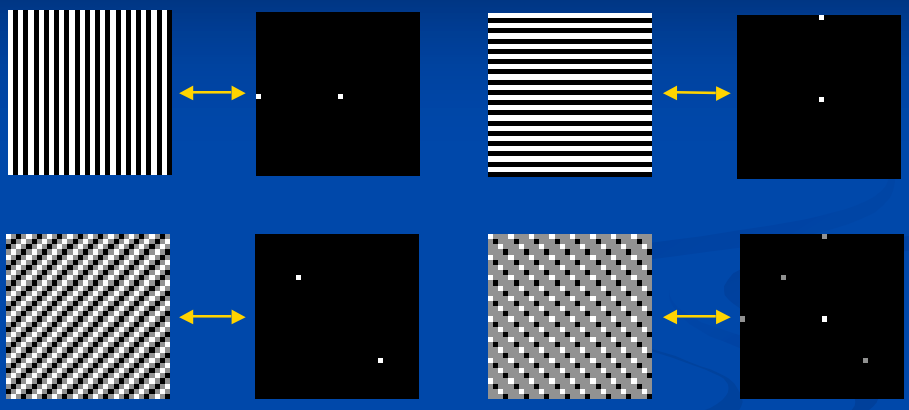


Image from http://www.fmrib.ox.ac.uk/~stuart/lectures/lecture1/

1D Fourier Transform

2D Fourier Transform



k-space

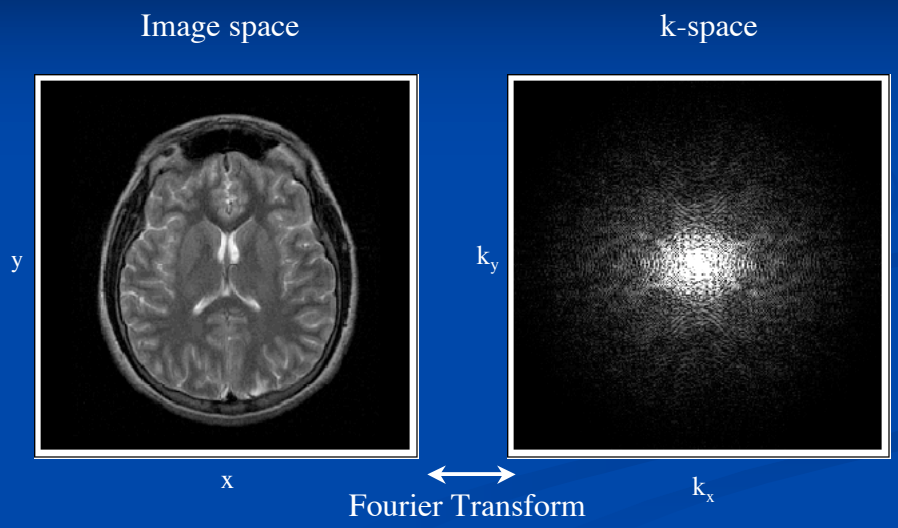


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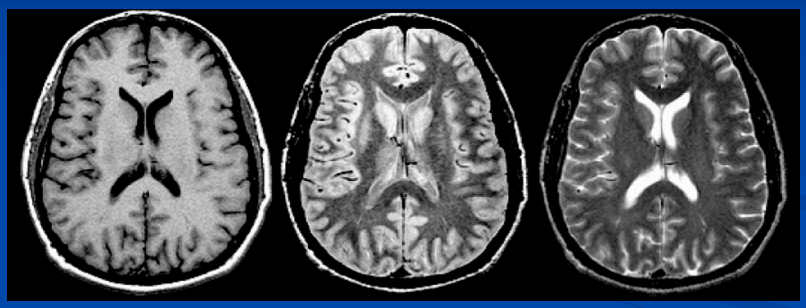
Image Contrast



T_1-weighted Density-weighted T_2-weighted

Image from Rick Buxton

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Unfolding the Cortex

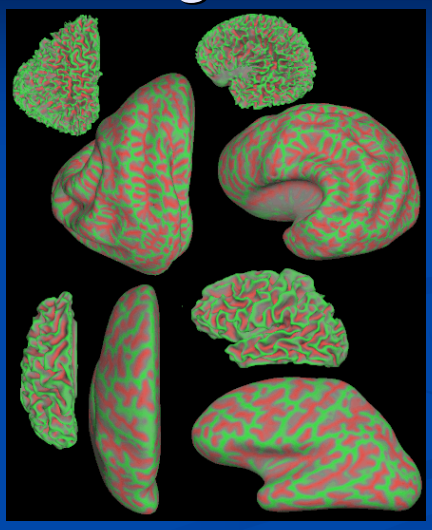


Image from Marie-Serane, UCSD

MR Angiography

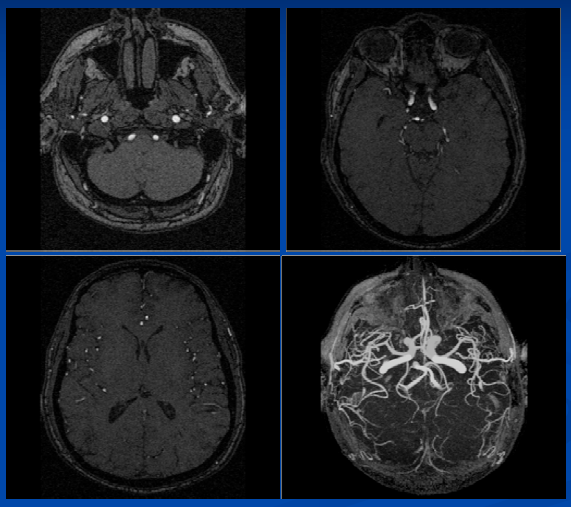


Image from R. Buxton

Perfusion Imaging with Contrast

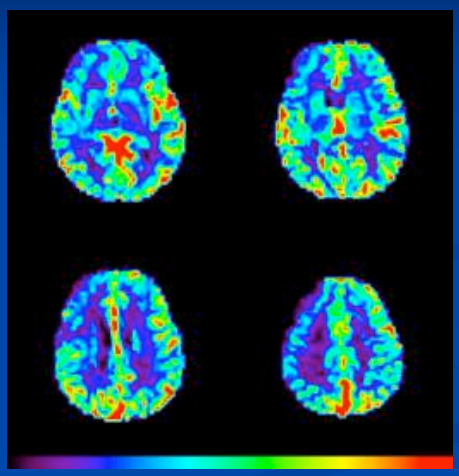


Image from http://irp.nhmrc.org/PowerPoint_HTML/pMRI/moyamoya_files/frame.htm

Perfusion Imaging with ASL

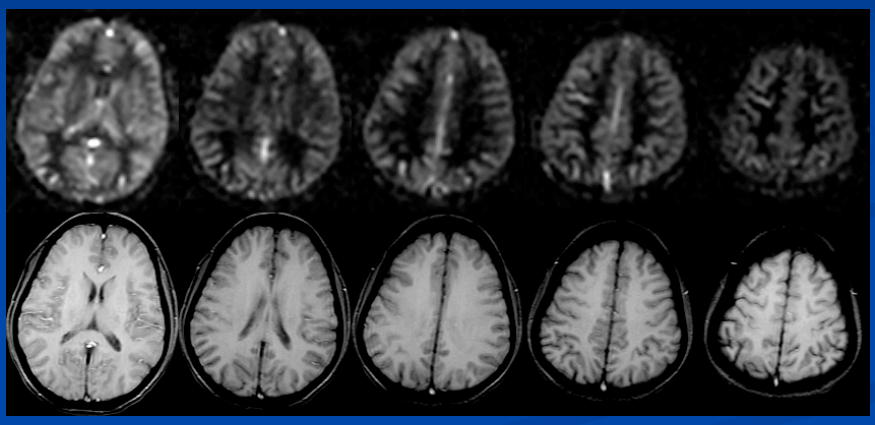


Image from F.G. Woermann

Cardiac Imaging

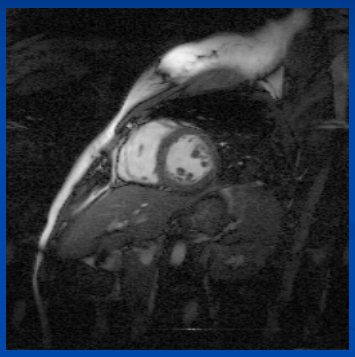


Image from http://www.bidmc.harvard.edu/cmr/cmash/smash.html

Cardiac Tagging

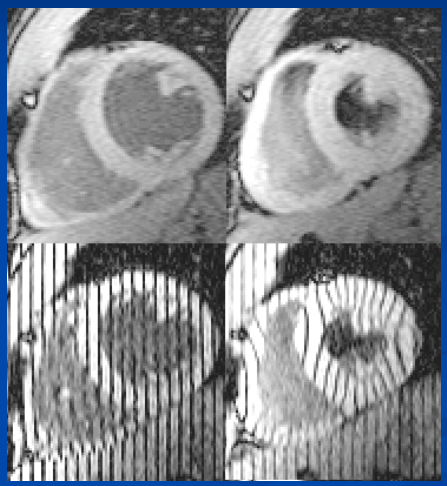


Image from http://www.mri.jhu.edu/~encyvieh/LabIntro/tagging.html

Hyperpolarized Helium

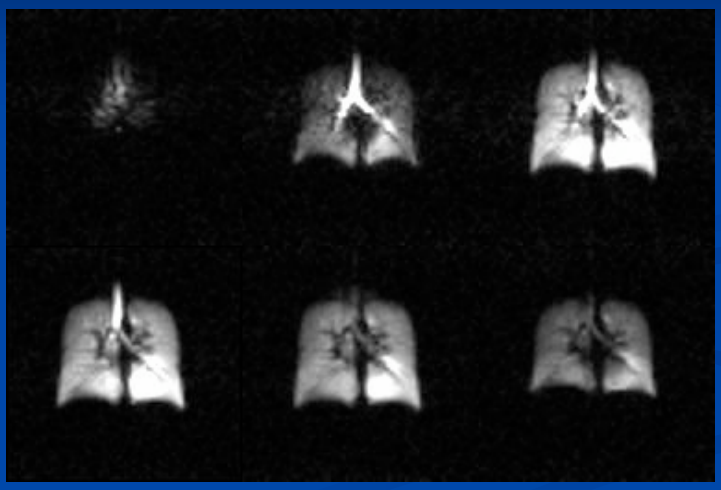
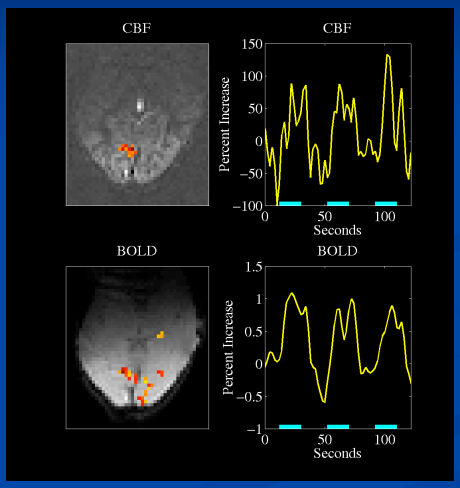


Image from http://www.physics.utah.edu/~saam/#RES

Functional MRI



Functional MRI

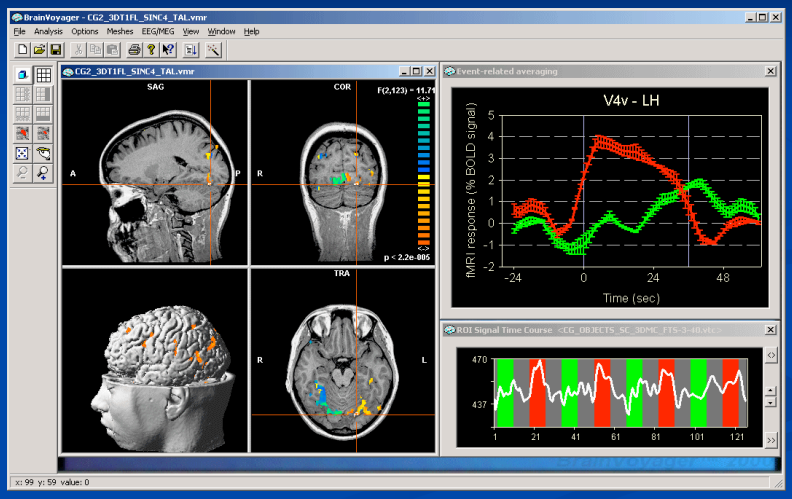


Image from http://www.brainvoyager.de/

Diffusion Tensor Imaging

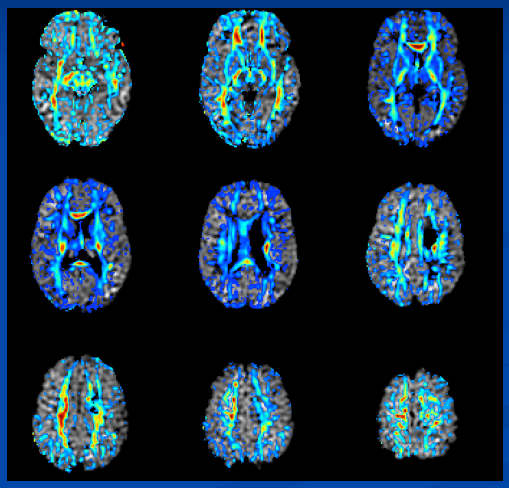


Image from L. Frank

MR Microscopy

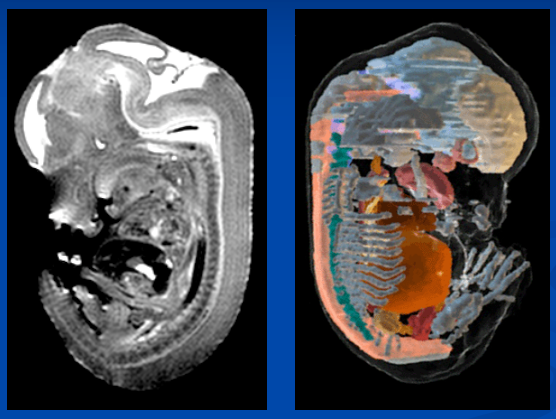


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Image from http://mouseatlas.caltech.edu/

MR Spectroscopy

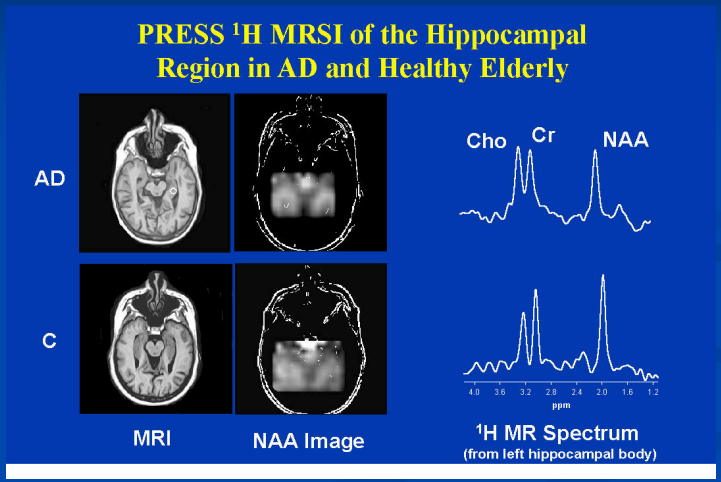

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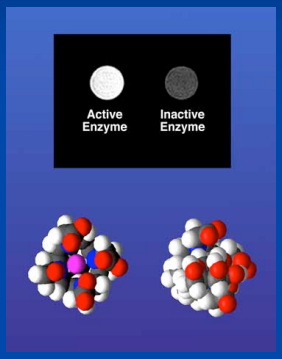
Image from http://www.sf.med.va.gov/mrs/ad/result.htm

Molecular Imaging



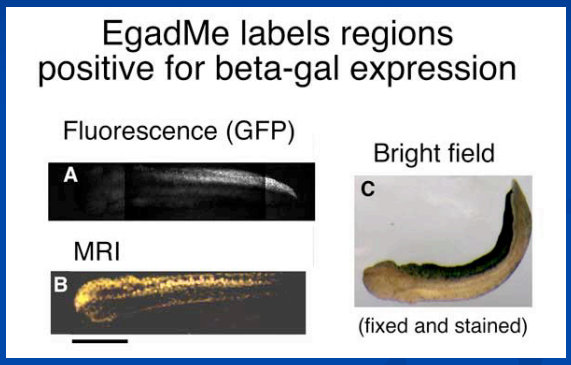


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Image from http://quad.bic.caltech.edu/~meadegroup/smart%20contrast%20agents.htm