

Introduction to Medical Imaging

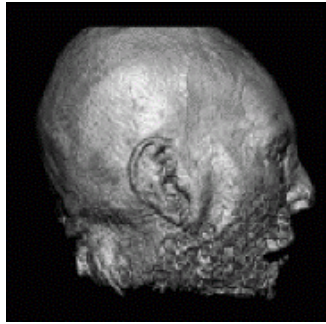
Lecture 1: Overview

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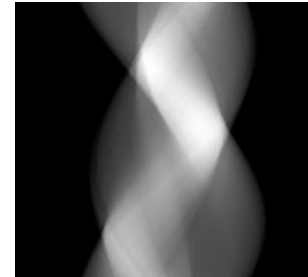
Overall Concept



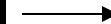
object



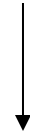
imaging device



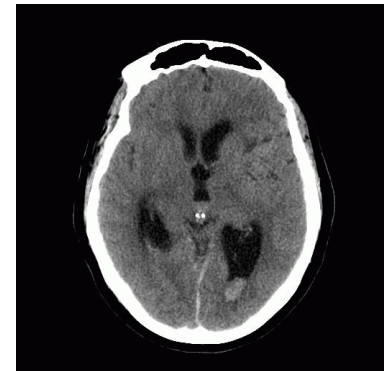
data



imaging
algorithm



reconstructed
cross-sectional
image



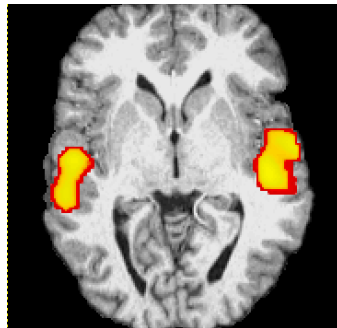
Imaging Modalities Overview

CT



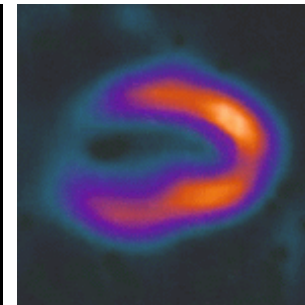
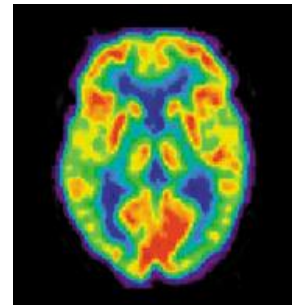
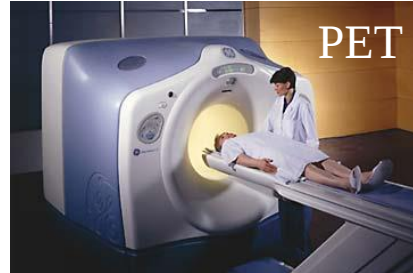
X-ray

MRI / fMRI



magnetic spin

Nuclear



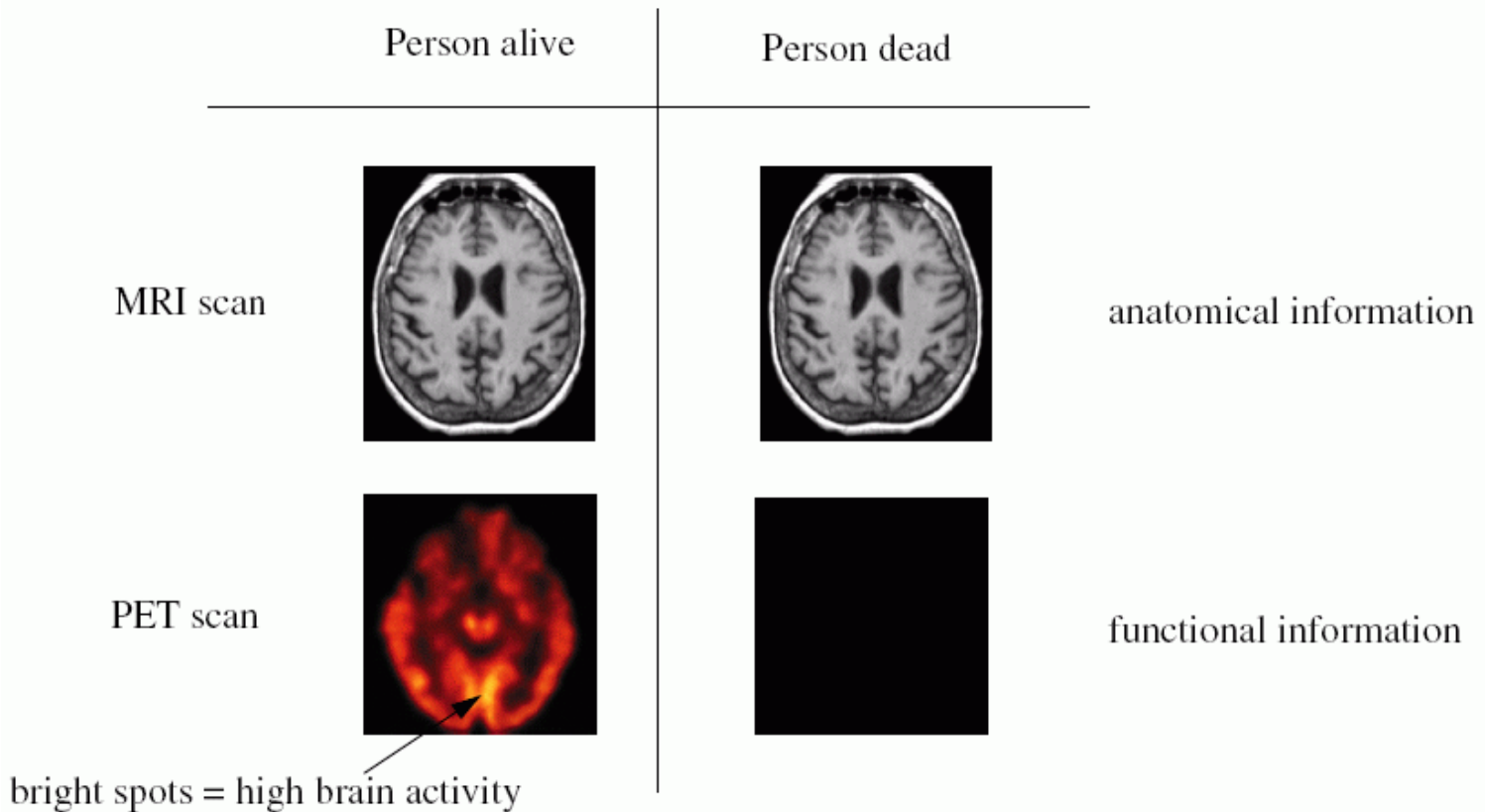
metabolic tracer X-ray
emission

Ultrasound



sound waves

Anatomic vs Functional Imaging



An MRI scan shows you that you have a brain

A PET scan shows that you use it

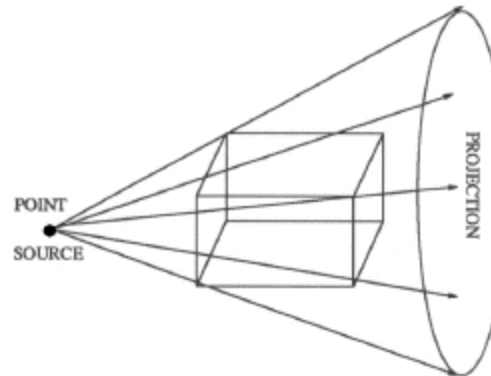
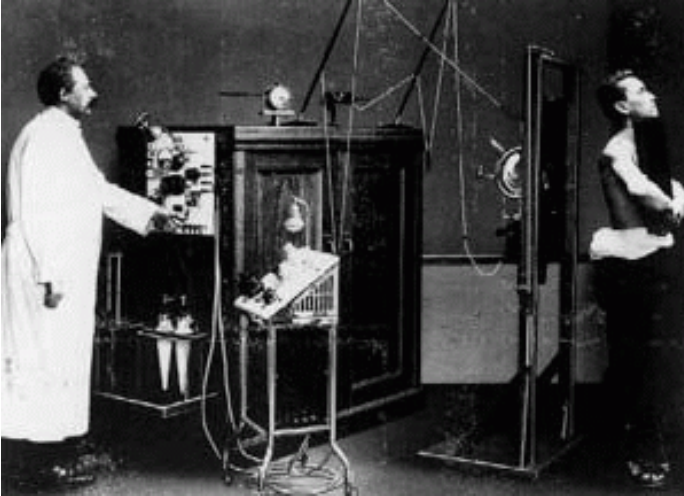
History: X-Rays

Wilhelm Conrad Röntgen

- 8 November 1895: discovers X-rays.
- 22 November 1895: X-rays Mrs. Röntgen's hand.
- 1901: receives first Nobel Prize in physics



An early X-ray imaging system:



Note: so far all we can see is a projection across the patient:

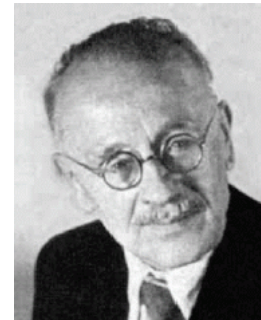
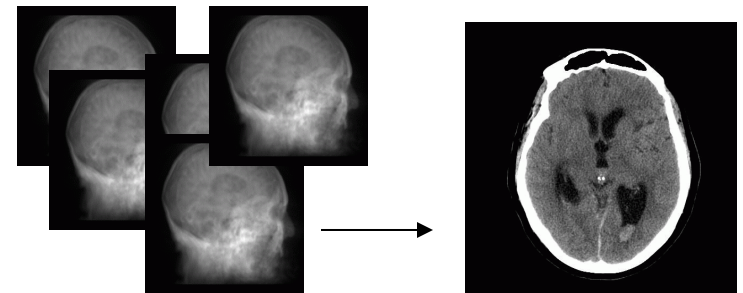
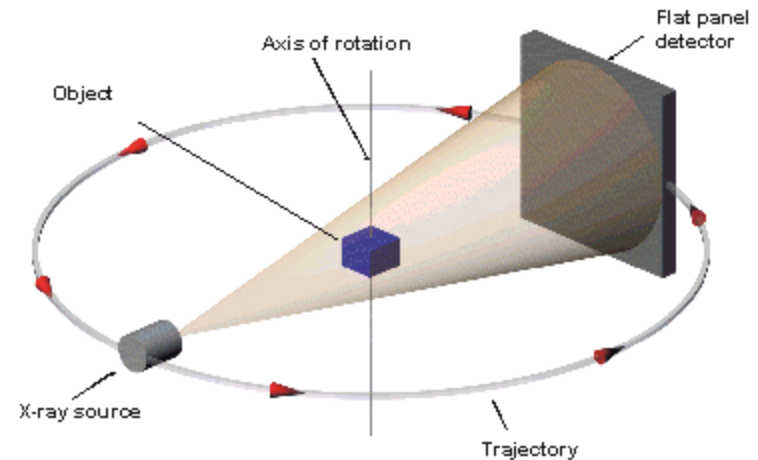
History: Computed Tomography

The breakthrough:

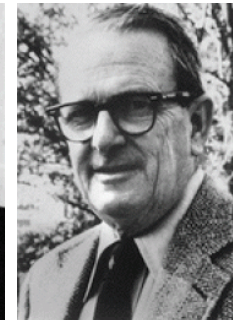
- acquiring many projections around the object enables the reconstruction of the 3D object (or a cross-sectional 2D slice)

CT reconstruction pioneers:

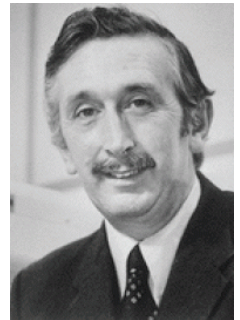
- 1917: Johann Radon establishes the mathematical framework for tomography, now called the Radon transform.
- 1963: Allan Cormack publishes mathematical analysis of tomographic image reconstruction, unaware of Radon's work.
- 1972: Godfrey Hounsfield develops first CT system, unaware of either Radon or Cormack's work, develops his own reconstruction method.
- 1979 Hounsfield and Cormack receive the Nobel Prize in Physiology or Medicine.



Radon

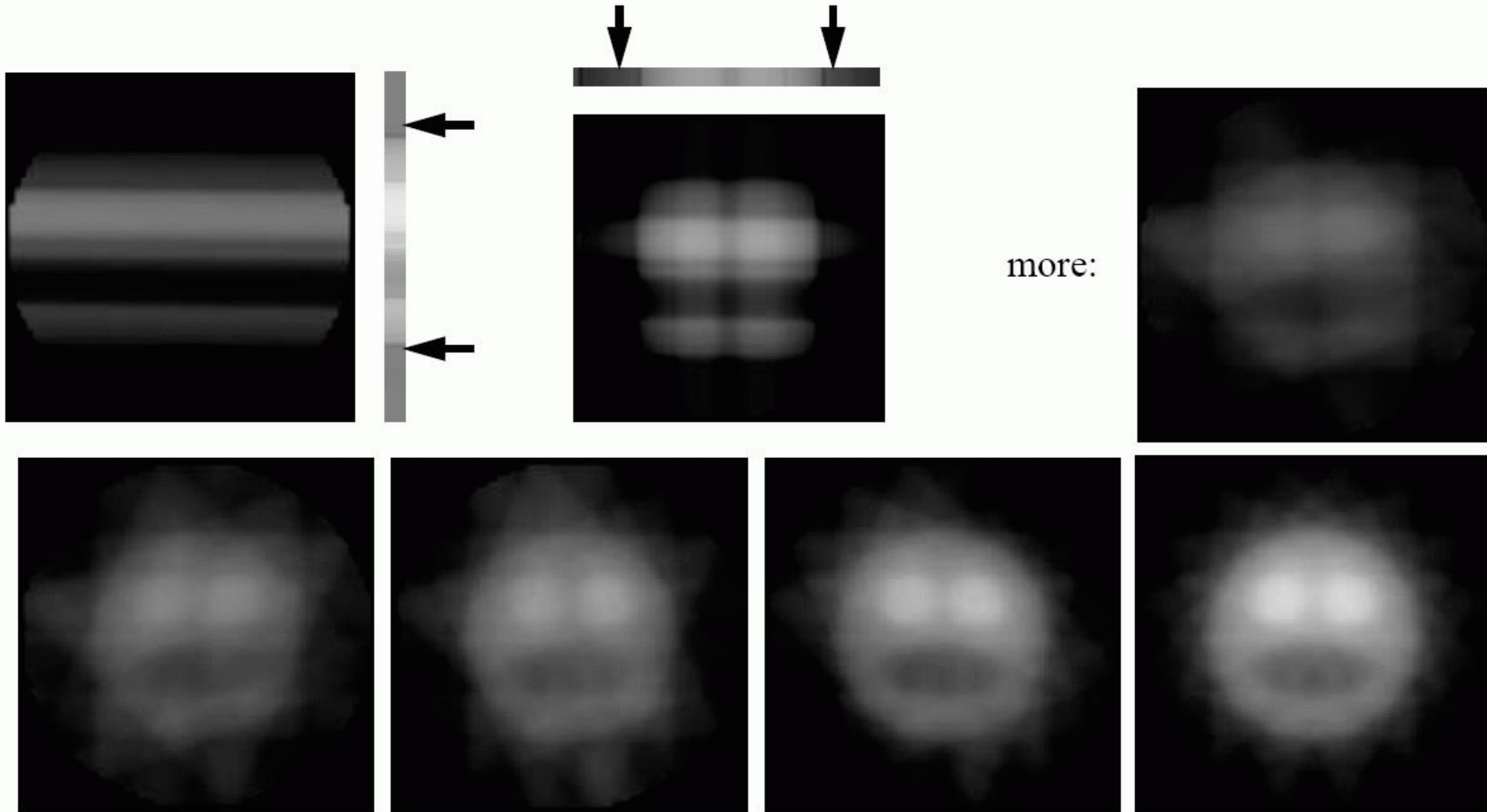


Cormack



Hounsfield

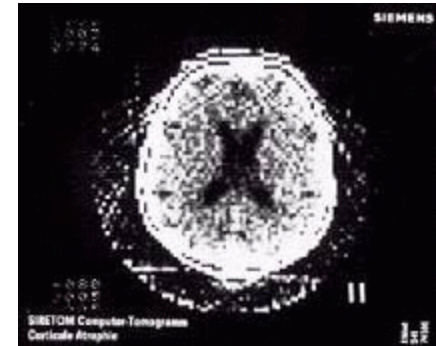
Computed Tomography: Concept



Computed Tomography: Past and Present

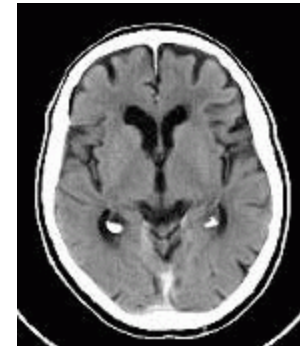
Image from the Siemens Siretom CT scanner, ca. 1975

- 128x128 matrix.



Modern CT image acquired with a Siemens scanner

- 512x512 matrix



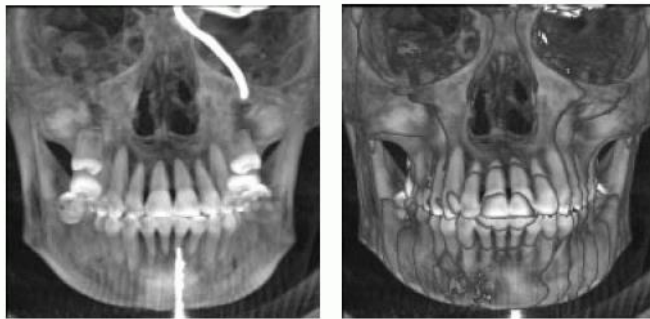
Slice Viewer



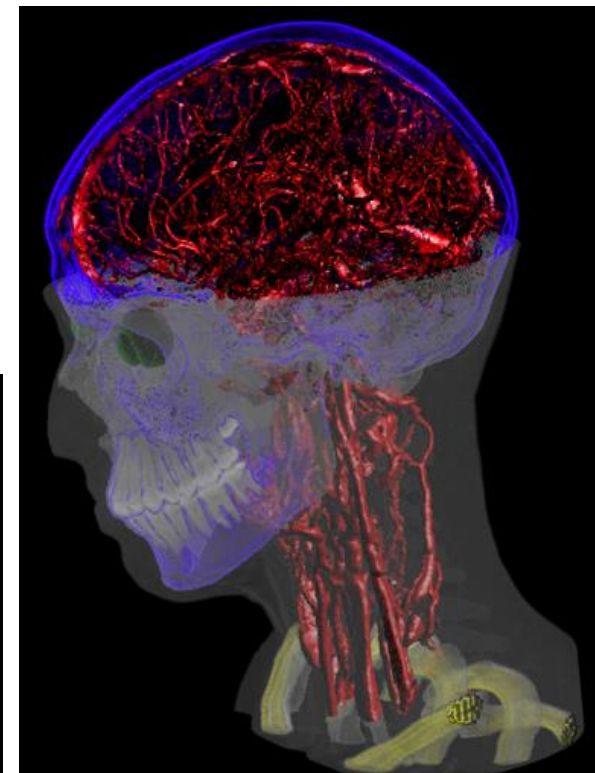
3D Visualization

Reconstructed object enables:

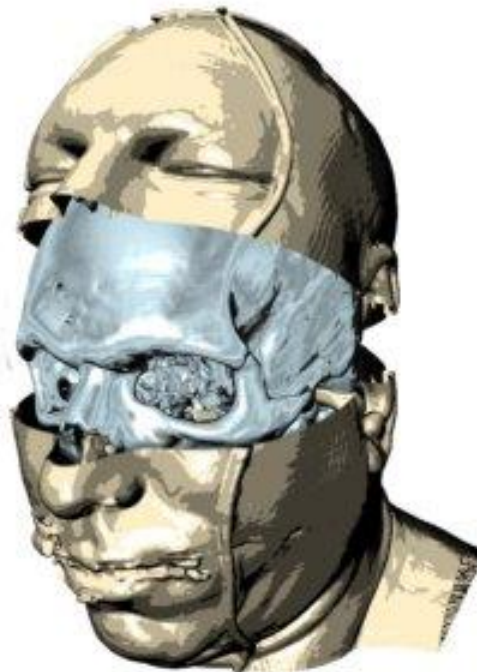
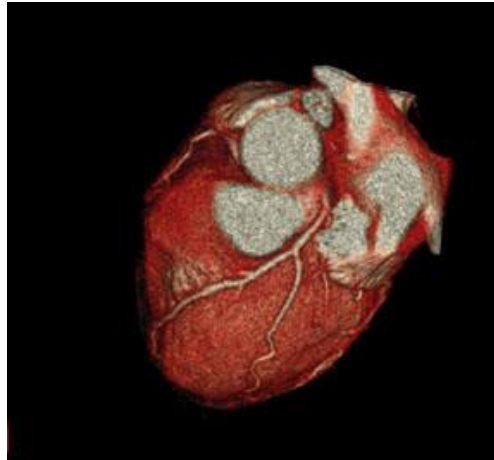
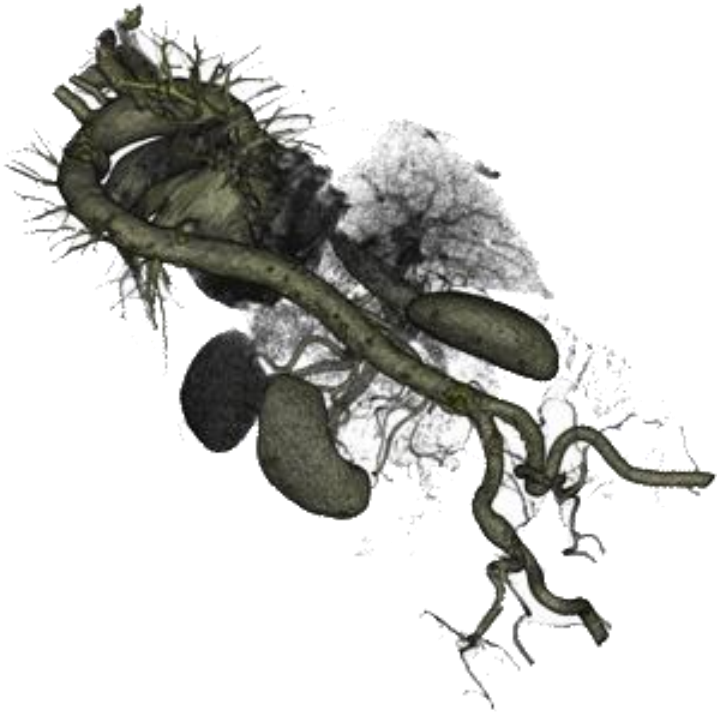
- Enhanced X-ray visualization from novel views:
- Maximum Intensity (MIP) visualization:



- Shaded object display:



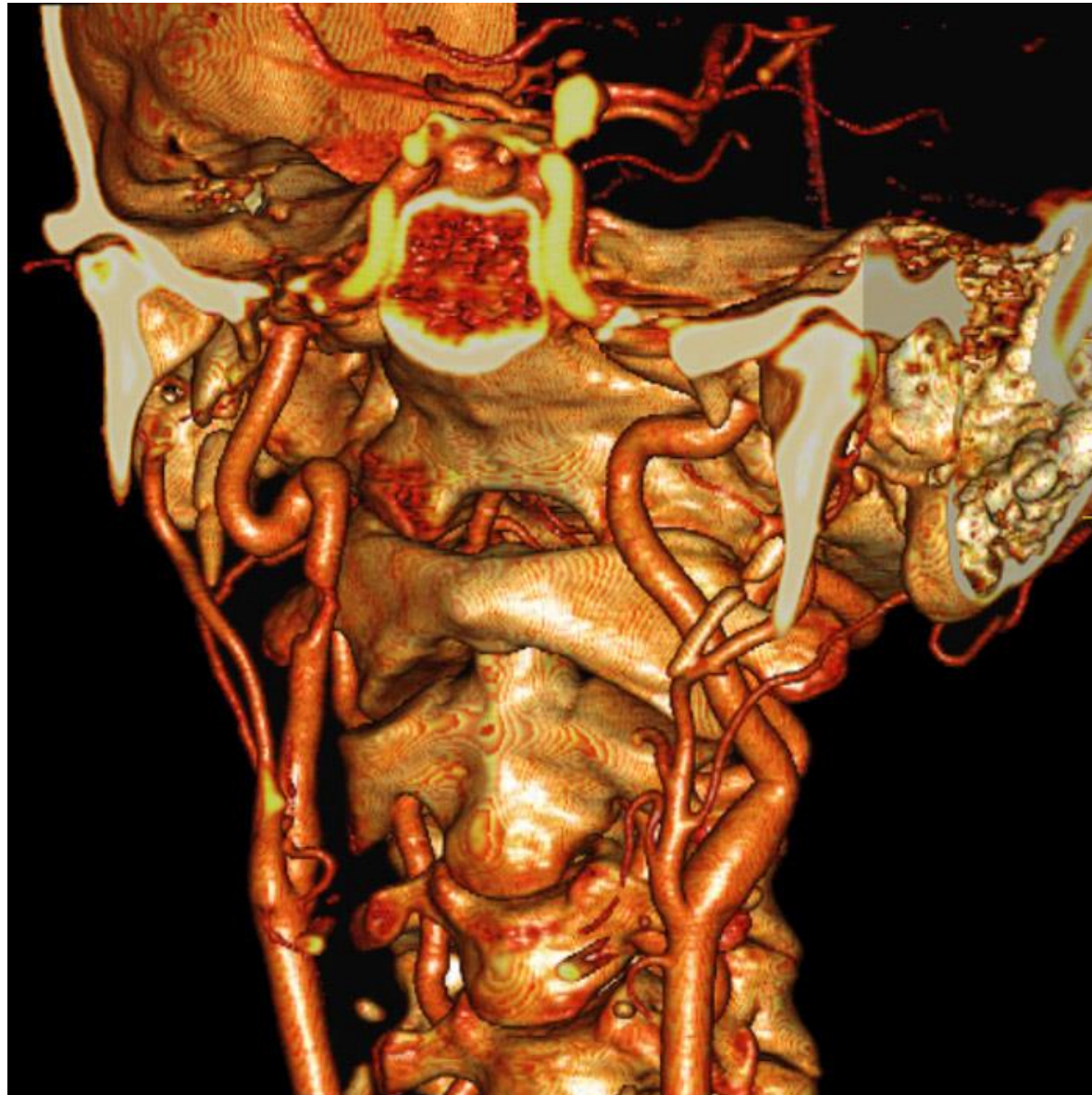
More Visualizations



Aortic Stent and Arterial Vessels



Carotid Stenosis



Virtual Medicine

Virtual colonoscopy, endoscopy, arthroscopy

Virtual therapy and surgery planning

Training platform



History: Ultrasound

1942: Dr. Karl Theodore Dussik,

- transmission ultrasound investigation of the brain



1955: Holmes and Howry

- Subject submerged in water tank to achieve good acoustic coupling

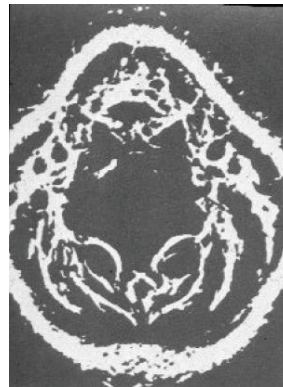
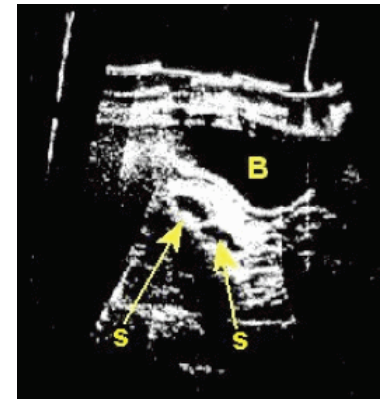


image of normal neck

1959: Automatic scanner, Glasgow

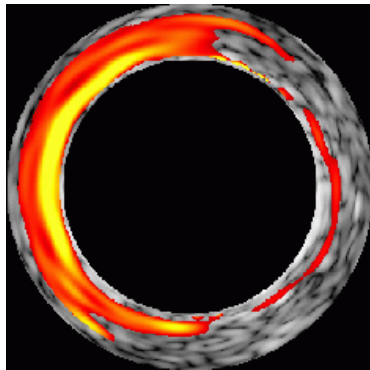


twin gestation sacs (s) and bladder (B).

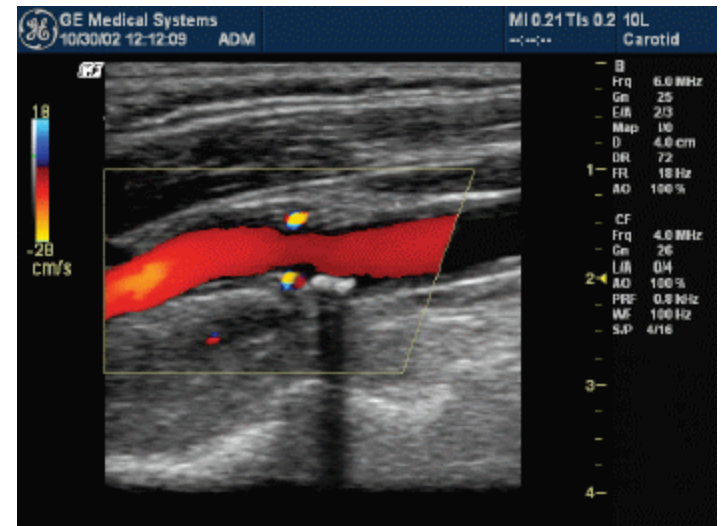
Ultrasound: Present



3D Ultrasound



Intravascular ultrasound



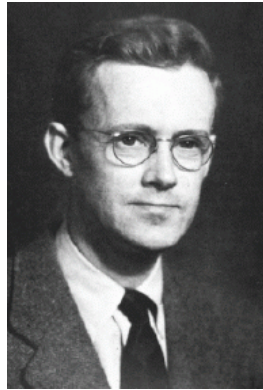
Doppler ultrasound

History: MRI

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



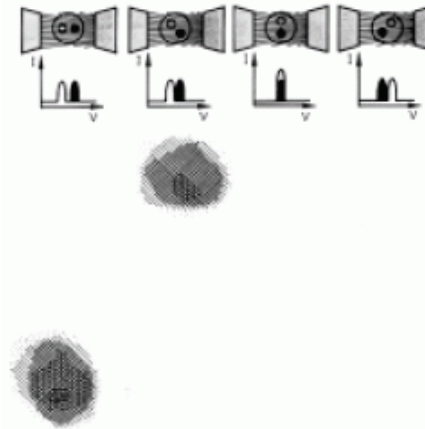
Bloch



Purcell



Lauterbur



1973: Paul Lauterbur (Stony Brook University) published first MRI (Magnetic Resonance Imaging) image in Nature.

- receives the Nobel Prize in Physiology or Medicine in 2003

Late 1970's: First human MRI images conceived

Early 1980's: First commercial MRI systems available

1993: Functional MRI in humans demonstrated

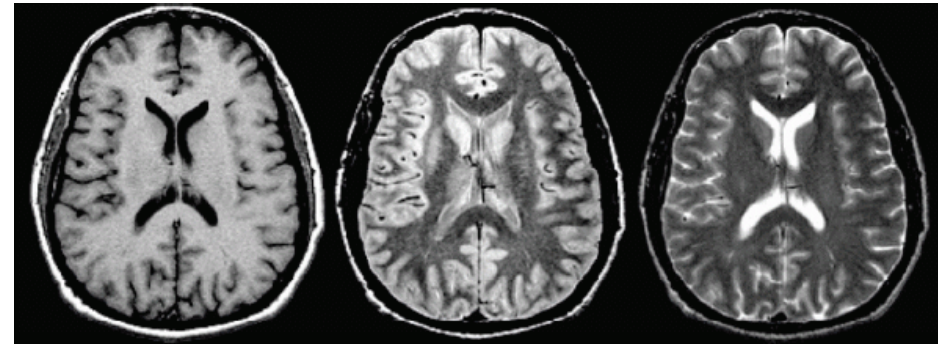
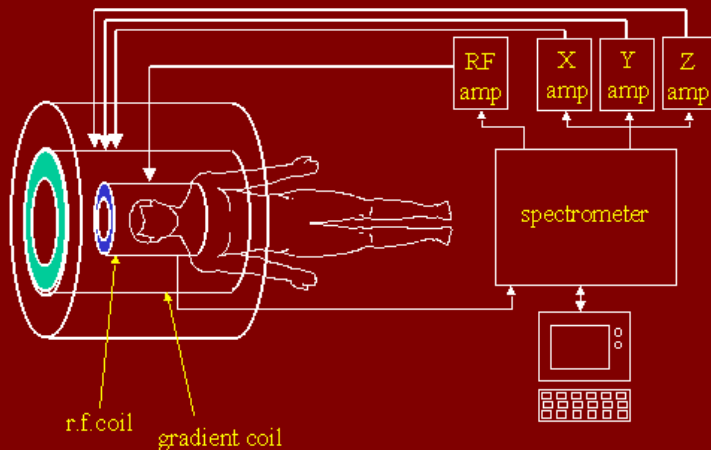
MRI Concept

MRI measures the effects of magnetic properties of tissue

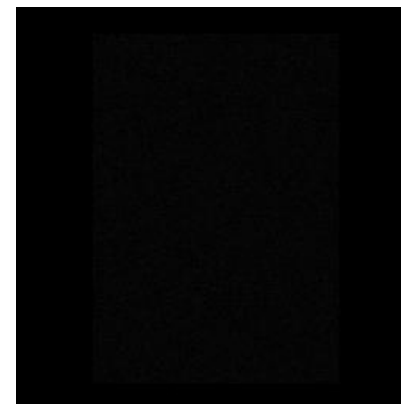
- these effects are tissue-specific
- also specific to blood perfusion / oxygenization (functional MRI)

MRI is very versatile (but also more expensive than CT)

MRI System Block Diagram



T1-weighted density-weighted T2-weighted

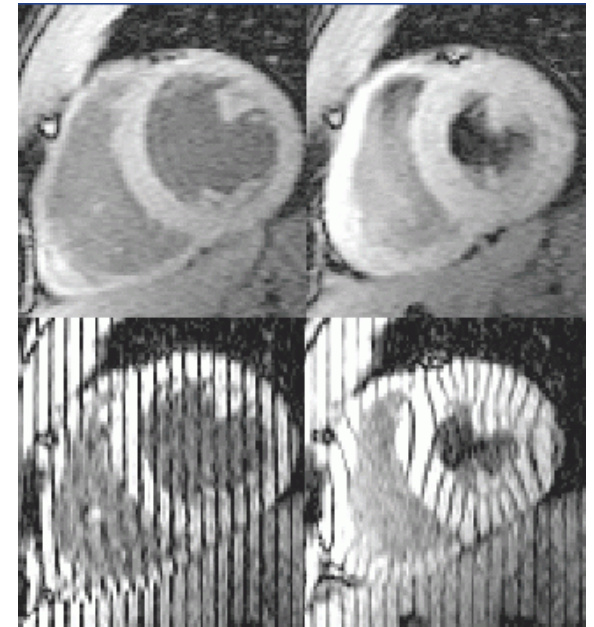


slice viewer

MRI Applications

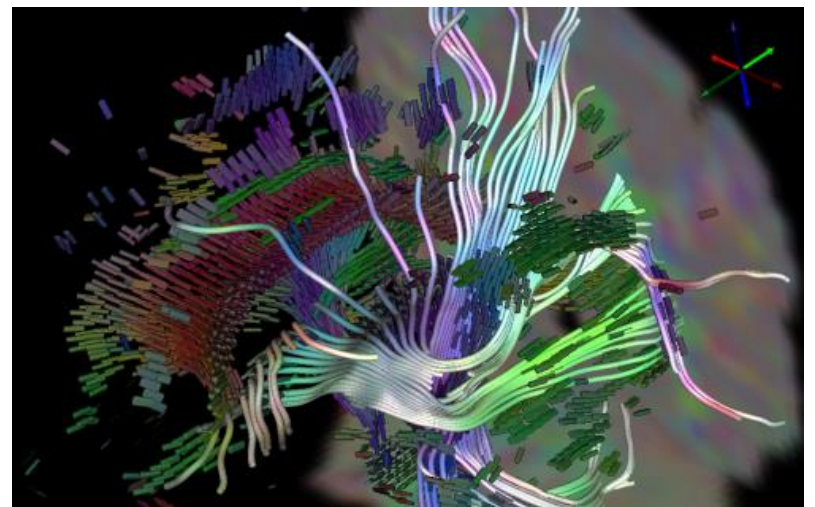
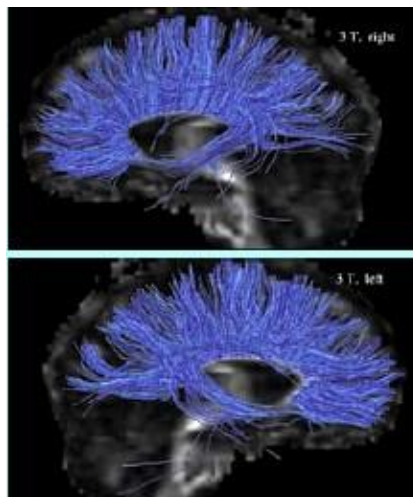
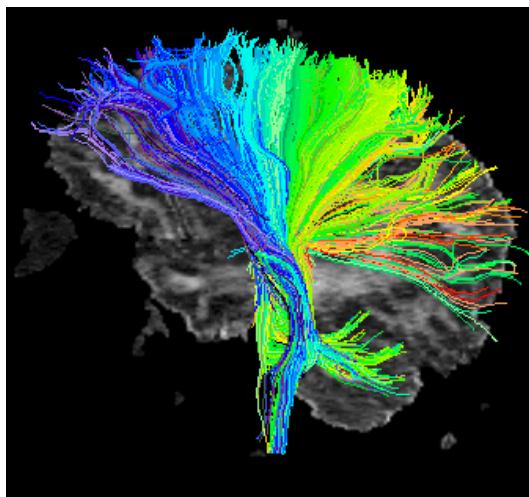
Cardiac MRI

- measures the distortion of “tags” to assess motion of the heart tissue



Diffusion Tensor Imaging

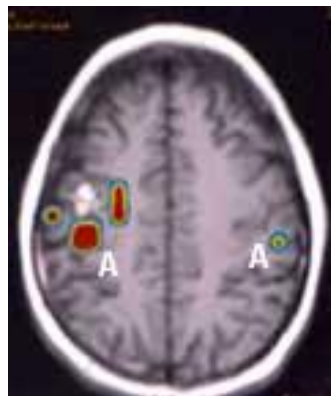
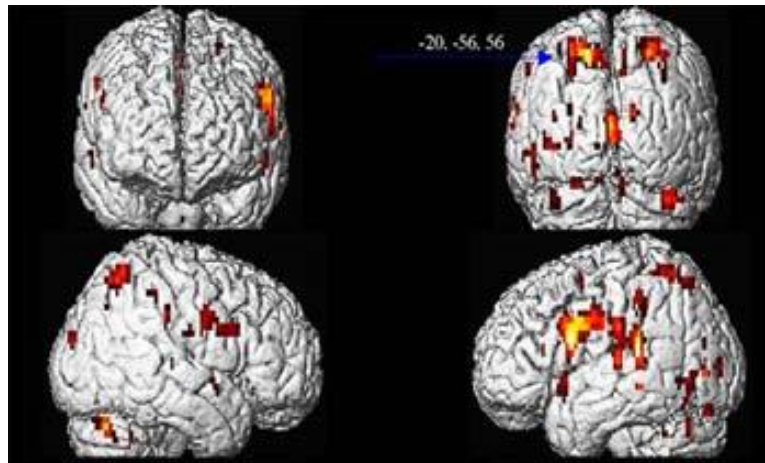
- measures the diffusion of water
- allows the tracking of nerve fibers in the brain (white matter)



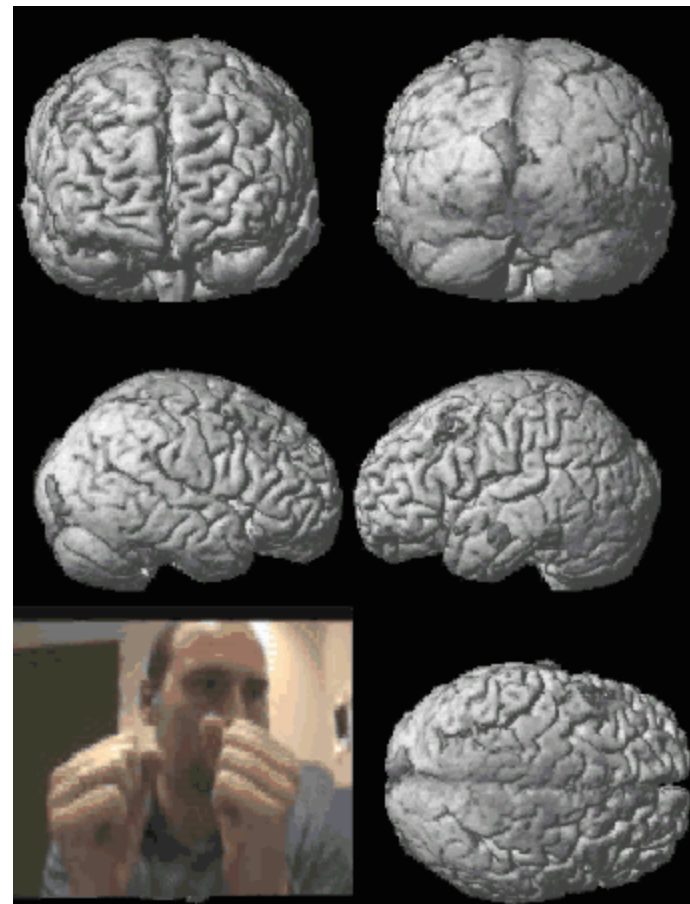
MRI Applications

Functional MRI

- allows to assess brain activity during certain tasks
- valuable for brain functional studies, but also for surgery planning and diagnosis



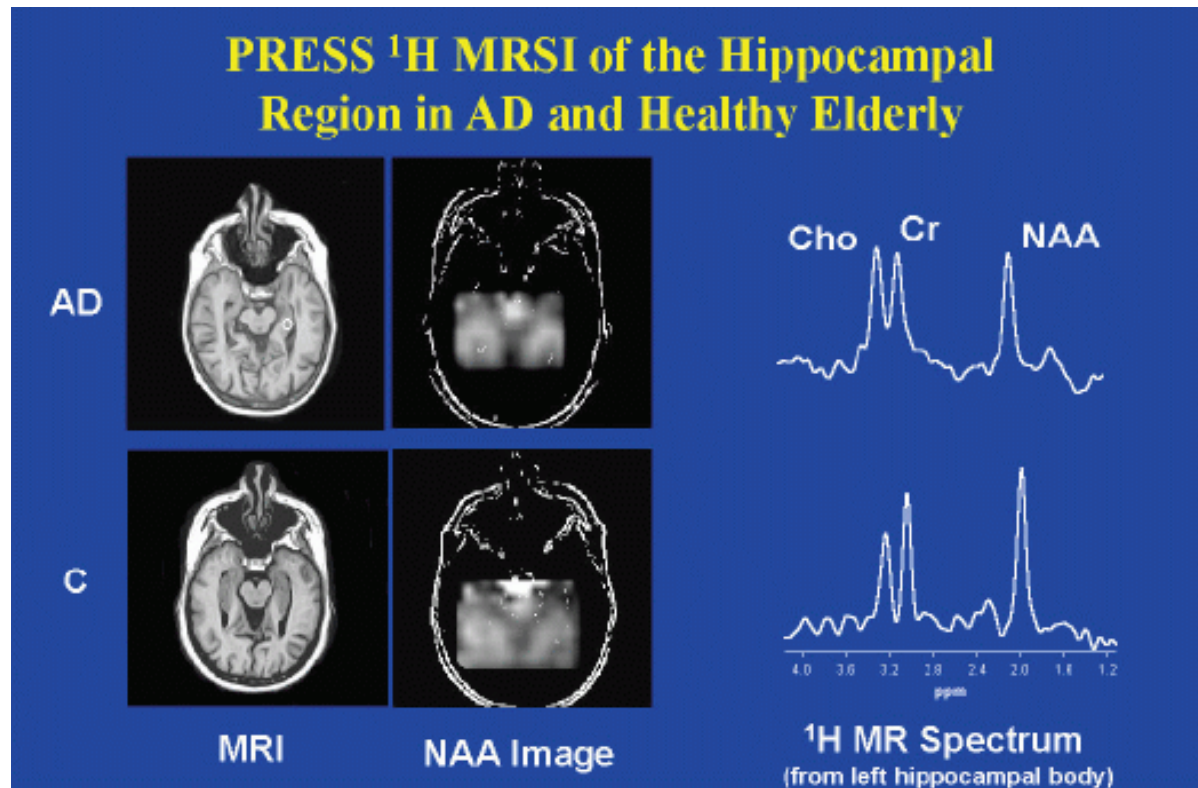
A. Motor cortex activity with left finger tapping



MRI Applications

MR Spectroscopy

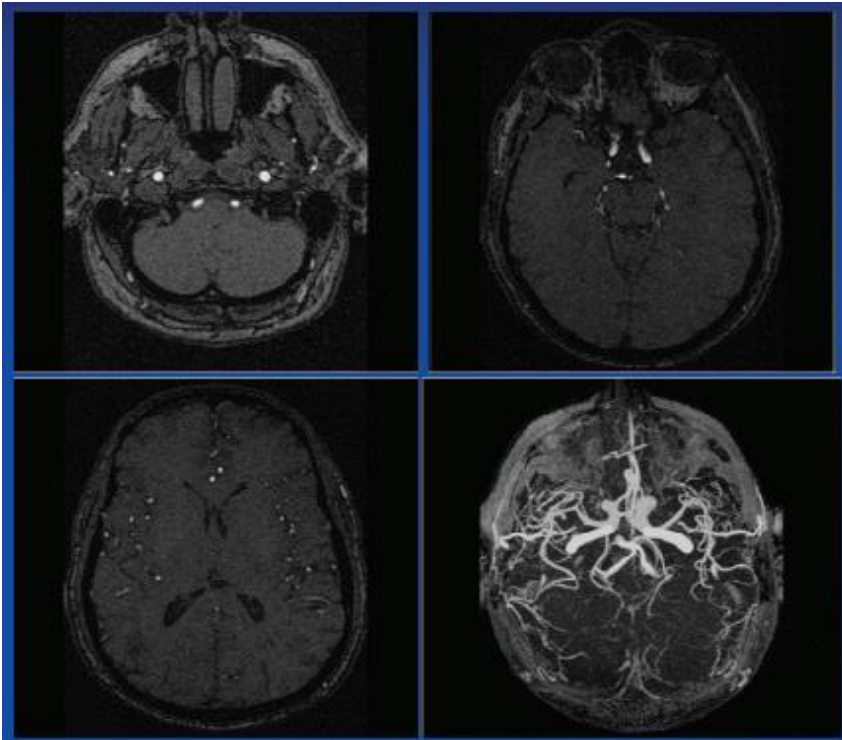
- measures the distribution of chemicals in each “voxel” of the brain



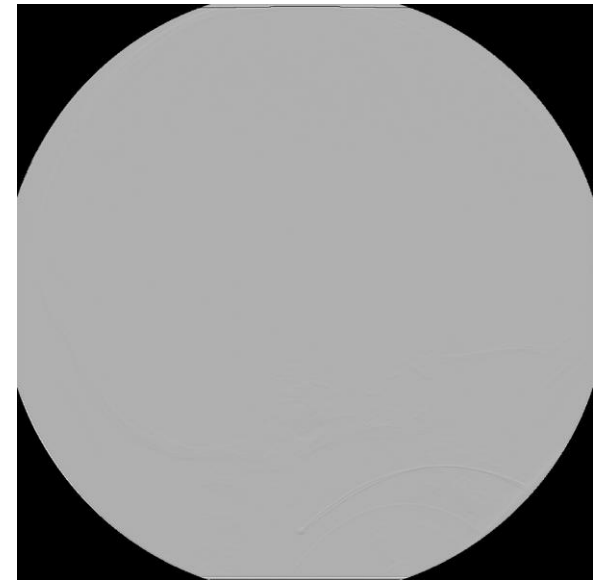
MRI Applications

MR Angiography

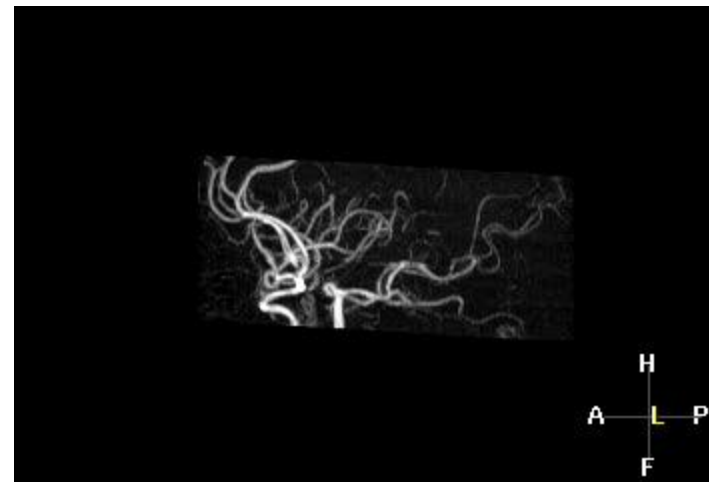
- magnetizes the bolus of blood, enhances vessels
- similar effects to X-ray angiography, but non-invasive



MR angiography



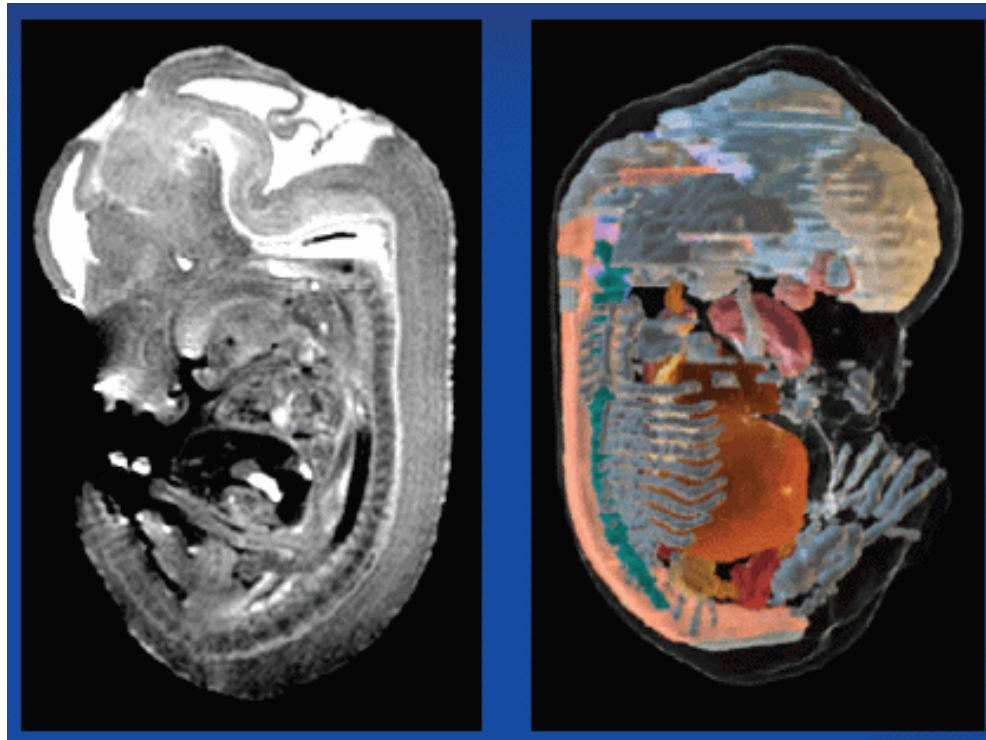
X-ray angiography



MRI Applications

MR Microscopy

- can resolve volumes of down to 50 mm^3 (clinical MR does 1 mm^3)
- use for small animal experiments (in place of destructive histology)



Credits

Most historical data and some images were taken from a similar presentation by Dr. Thomas Liu, UC San Diego

Other images are due to (list not complete):

- Joe Kniss, U Utah
- Gordon Kindlmann, U Utah
- Markus Hadwiger, VRVis
- Stefan Bruckner, U Vienna
- Naeem Shareef, Ohio State U
- Viatronix, Inc.
- Phillips Medical