



BIOMEDICAL ENGINEERING: HISTORICAL PERSPECTIVES AND PRESENT STATUS

Biomedical Engineering

- Medicine and technology have inspired and fascinated mankind since its early beginnings
- Although art of medicine has long history, evolution of technology-based health care system capable of providing wide range of effective diagnostic and therapeutic treatments is relatively new
 - ▣ Technical instruments and devices have always had their place in medicine
- *Biomedical Engineering* is the discipline that merges technology and medicine

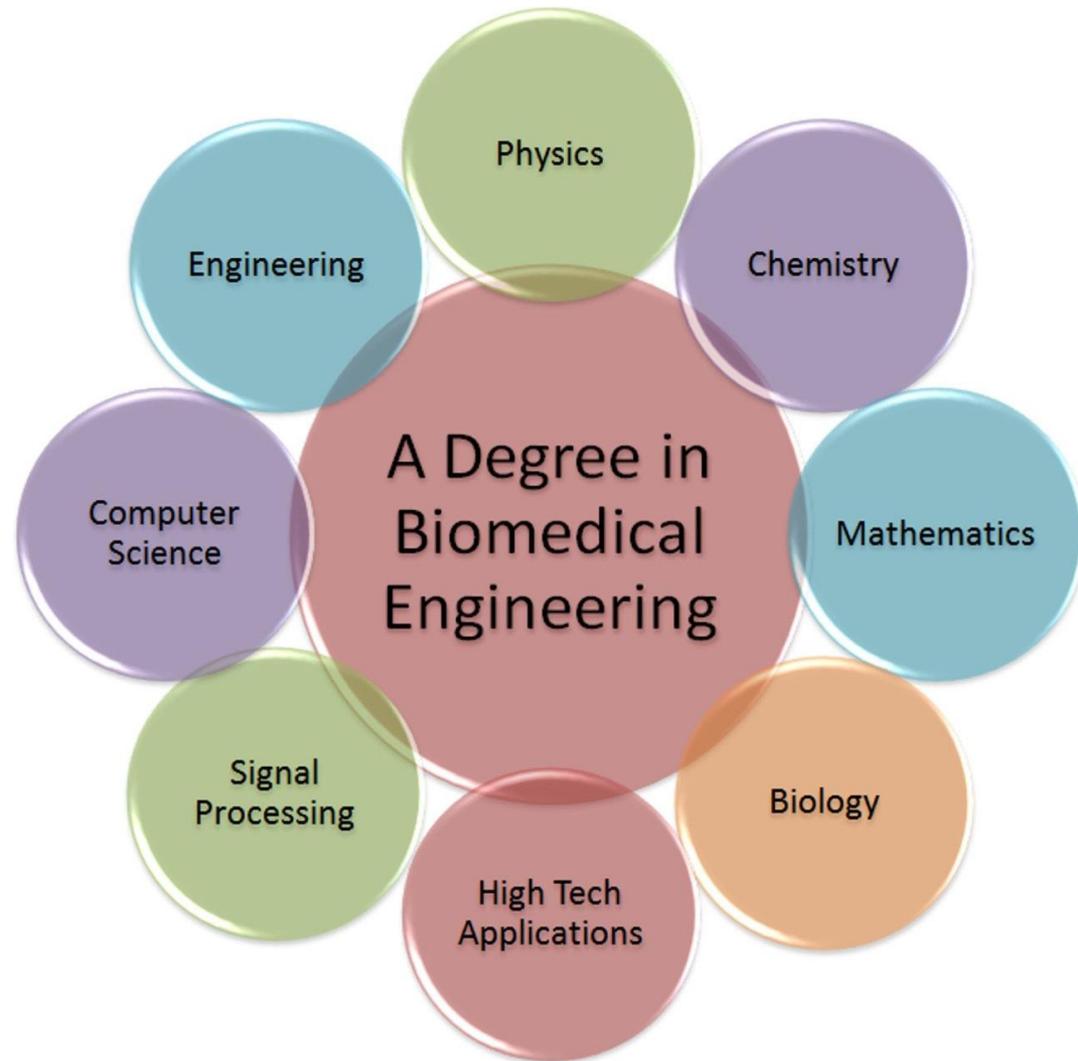
Role of Biomedical Engineering

- Biomedical engineering emerged as integrating medium for two dynamic professions: medicine and engineering and has assisted in struggle against illness and disease
- Biomedical engineering provides tools (such as biosensors, biomaterials, imaging, and artificial organs) that health care professionals can use for research, diagnosis, and treatment
- Biomedical engineers serve as relatively new members of the health care delivery team seeking new solutions for difficult health problems confronting mankind
- Role summary: *provide tools and solve medical technology problems*

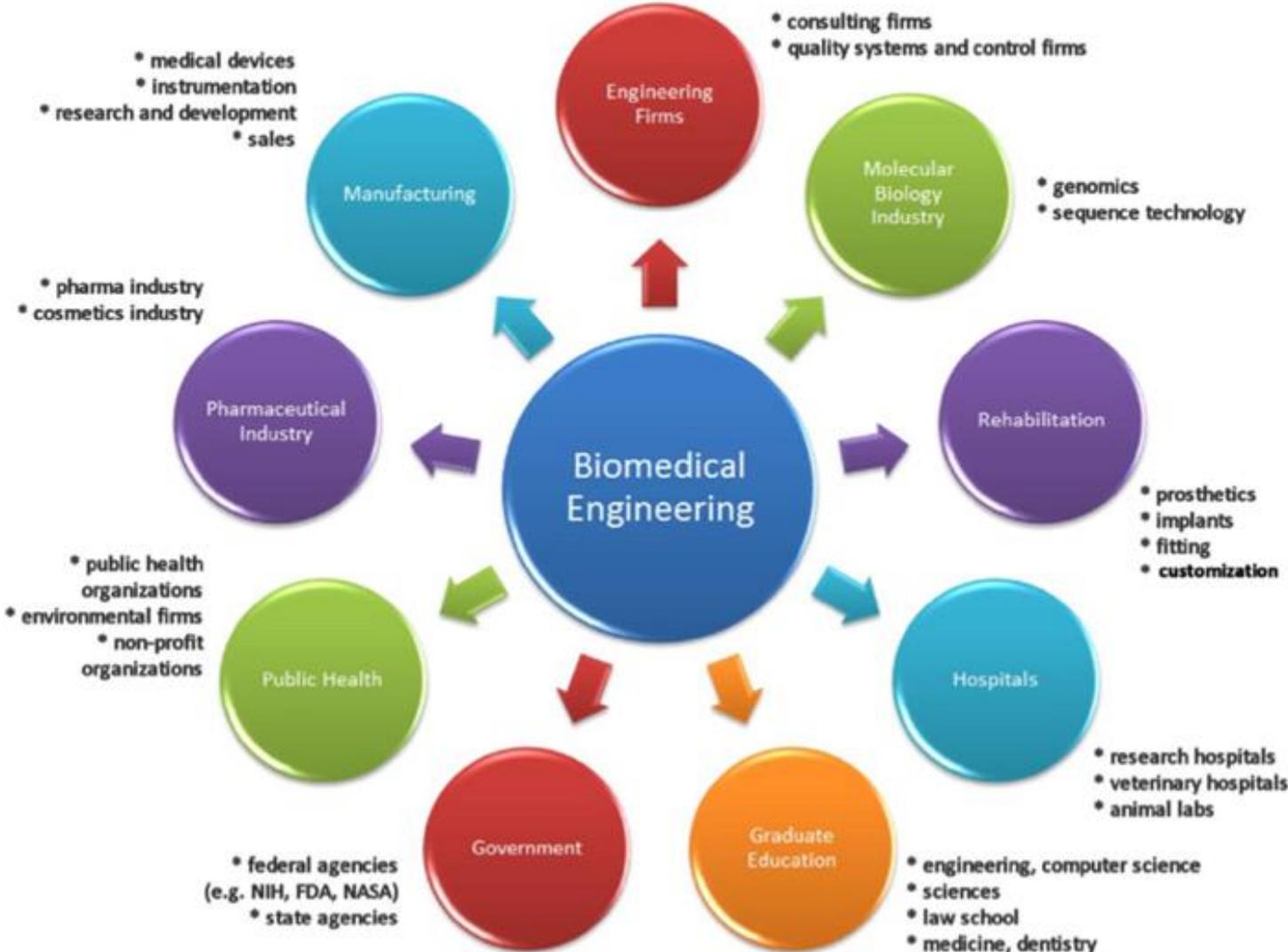
Components of Biomedical Engineering

□ Graduate:

- Bioengineer
- Biomedical Engineer
- Biological Engineer
- Medical Engineer
- Clinical Engineer



Biomedical Engineering Employment



Example Professional Societies

- Association for the Advancement of Medical Instrumentation (AAMI)
- IEEE Engineering in Medicine and Biology Society (IEEE EMBS)
- International Federation for Medical & Biological Engineering (IFBME)
- Biomedical Engineering Society (BMES)
- Saudi Scientific Society of Biomedical Engineering (SSSBE)



IEEE



IFMBE

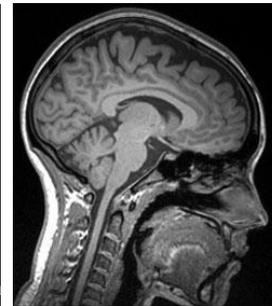
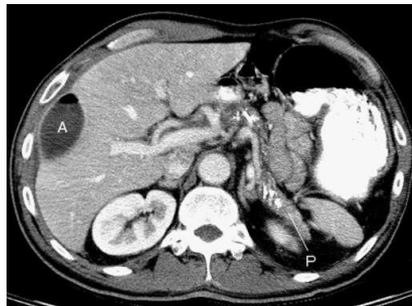
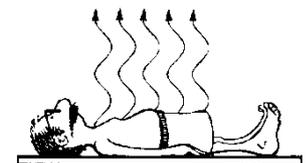
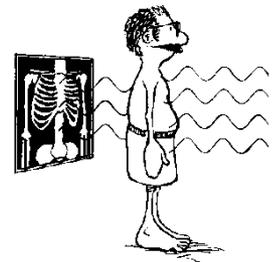
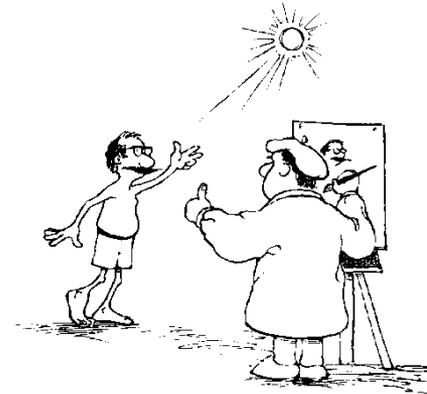


BMES

BIOMEDICAL ENGINEERING SOCIETY™

History Example: Medical Imaging

- Methodology to measure and map a useful property of human tissues
- Non-invasive or minimally-invasive
- Examples:
 - ▣ Reflection – photography, ultrasound
 - ▣ Transmission – x-rays
 - ▣ Radiation – MRI, PET/SPECT



History of Medical Imaging

- Before 20th century, medicine relied only on doctor's five senses to reach a diagnosis
 - ▣ Difficulties and low accuracy in many situations
 - ▣ Need for diagnostic surgeries that usually cause complications



History of X-Ray Imaging

- Start of medical imaging era from discovery of X-rays by Röntgen in 1895



BEFORE LEAVING THE EXHIBITION
"SEE"
THE WONDROUS
X RAYS
The
Greatest Scientific Discovery
of the Age.

By the aid of the New Light you are
enabled to see

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X RAY PHOTOGRAPHS TAKEN.



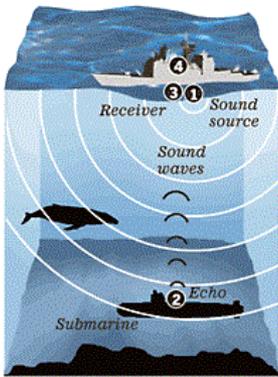
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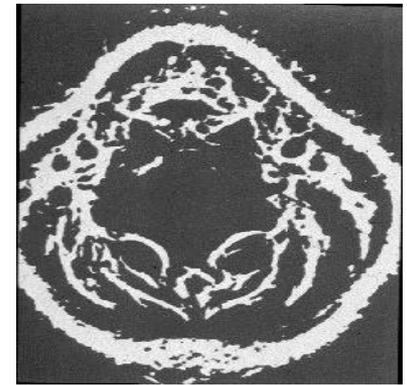
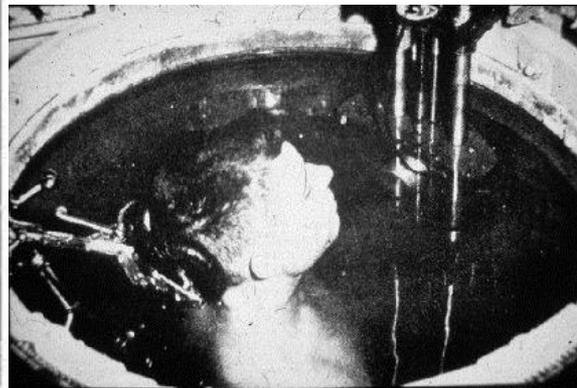


History of Ultrasound Imaging

- Basic ideas from military applications of Radar and Sonar.
- First medical application by George Ludwig in 1942

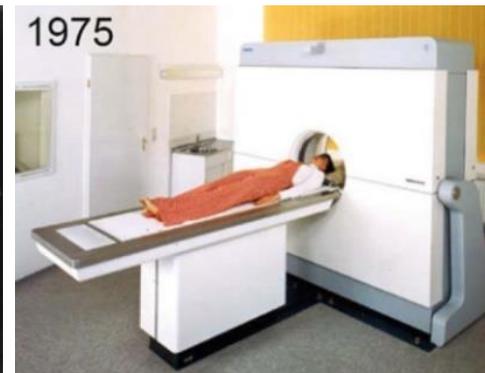
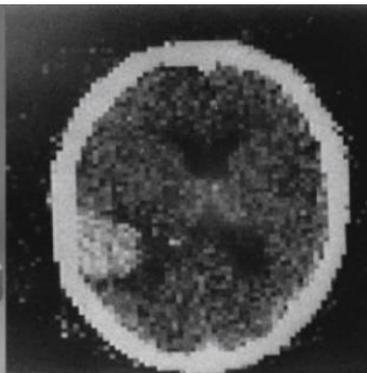
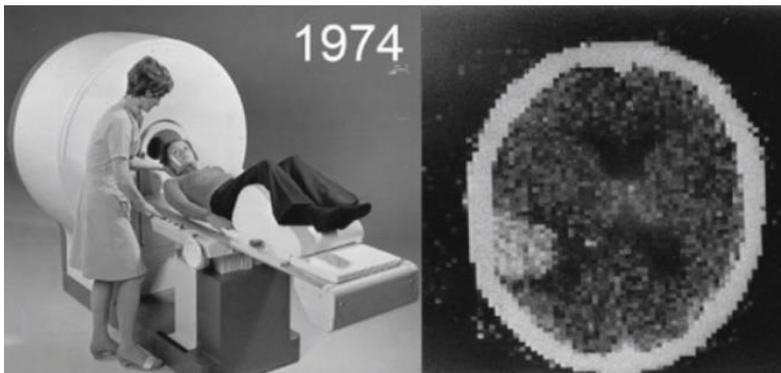


SOUND-WAVE PORTRAIT IN THE FLESH
A sonarlike device produces pictures of the human body's soft tissues which are invisible to X-rays.



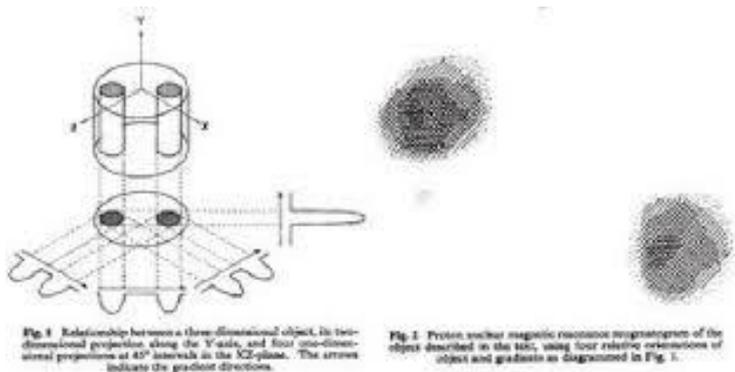
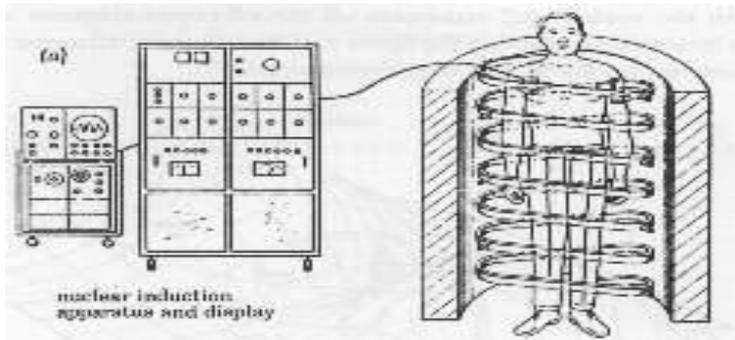
History of Computed Tomography

- First developed by Godfrey Hounsfield in 1971
 - ▣ Theory of image reconstruction developed in 1924 by Radon



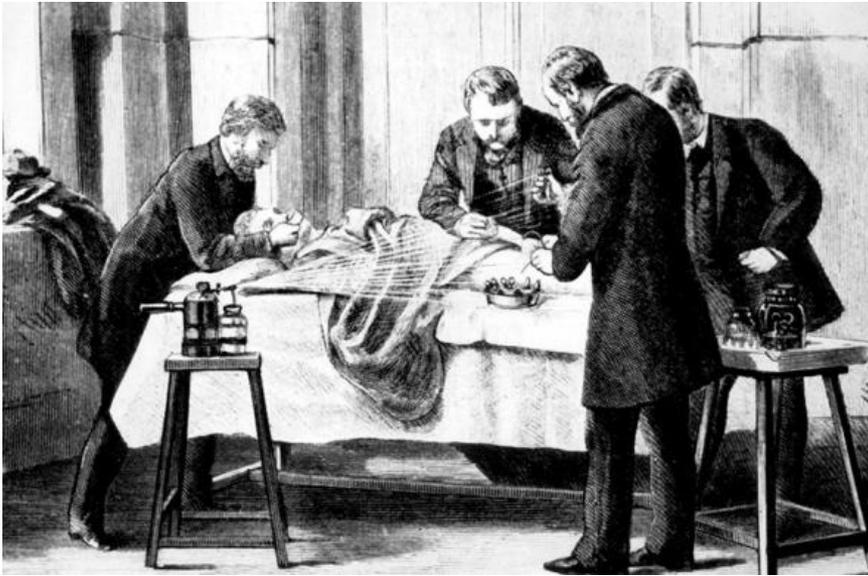
History of Magnetic Resonance Imaging

- First recorded images in 1973 by physicist Paul Lauterbur
 - ▣ Application of theory independently developed by Bloch and Purcell in 1946

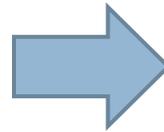


Now: Role of Imaging

- Reduce surgical interventions intended for diagnosis



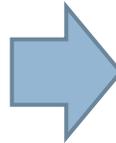
19th Century



Now

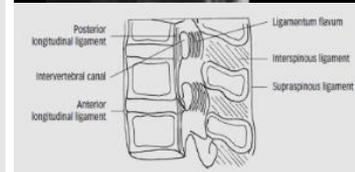
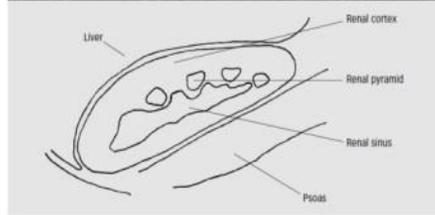
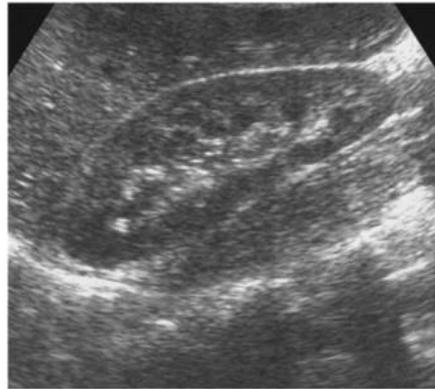
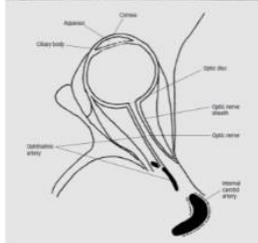
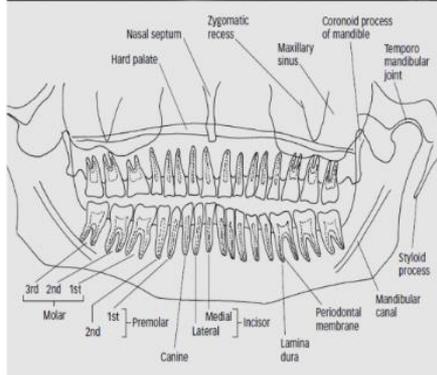
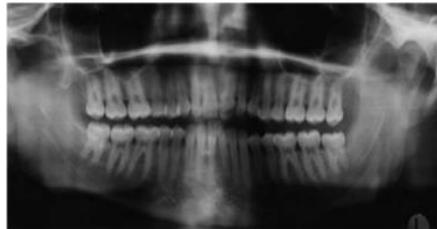
Anatomical Imaging

- Collection of images of internal organs to aid diagnosis

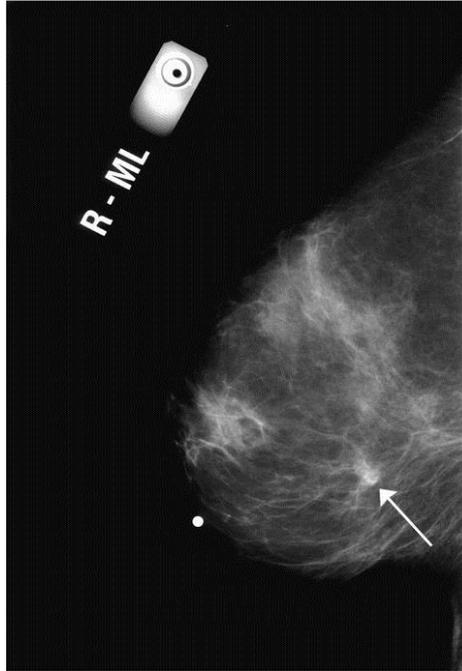


Anatomical Imaging

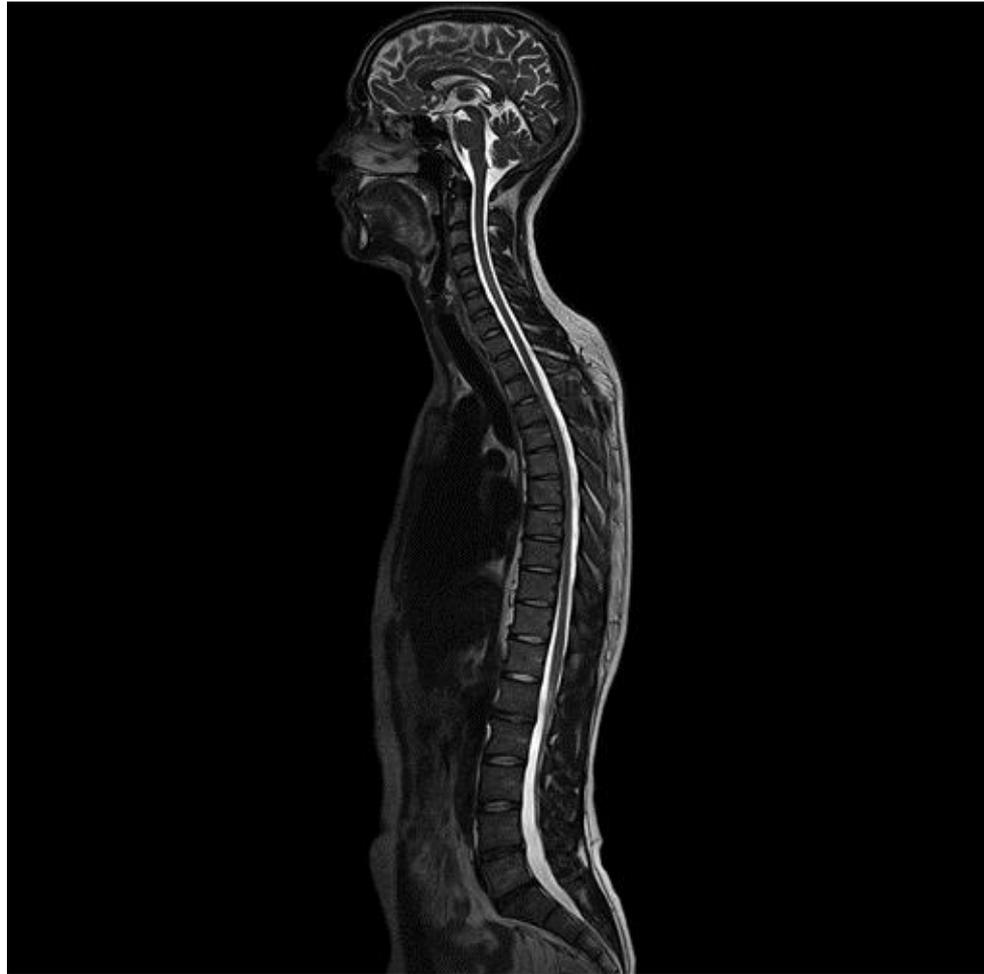
- Examples showing correlation with textbook anatomy



Anatomical Imaging: Tumor detection



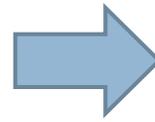
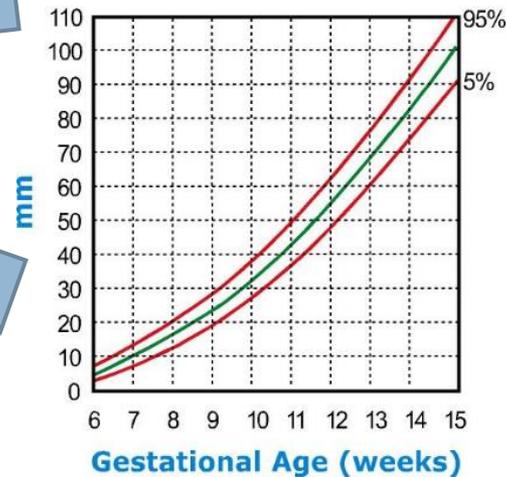
Anatomical Imaging: Full-Body Scan



Fetal Age Calculation From Ultrasound

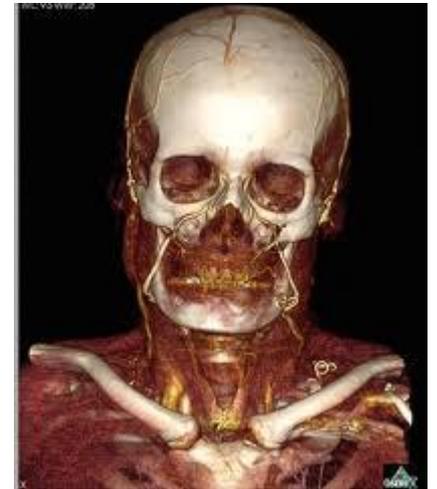


Crown-Rump Length



Age Estimation

3D Imaging

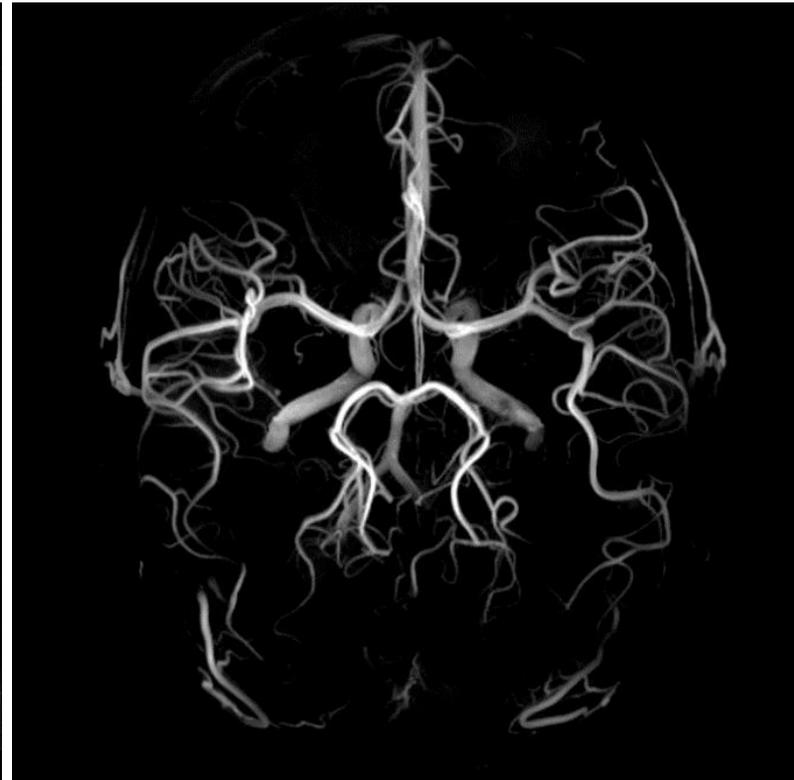
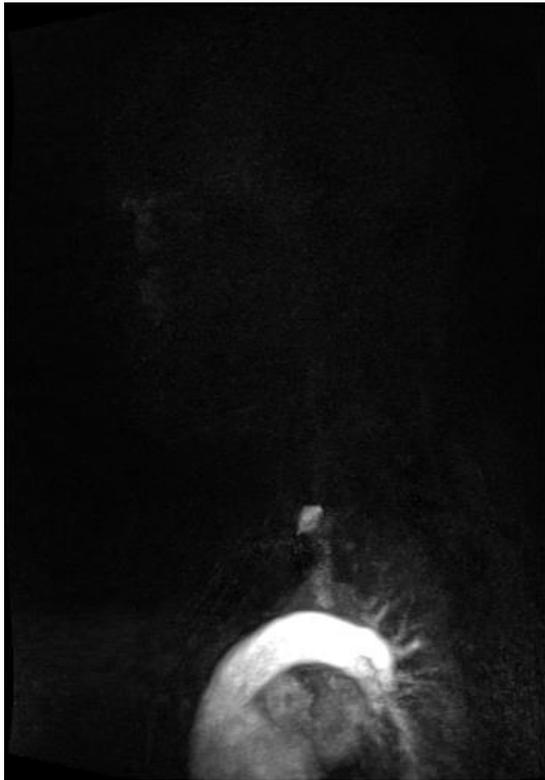


Angiography

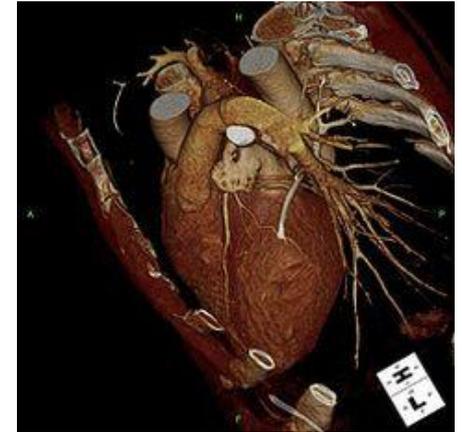
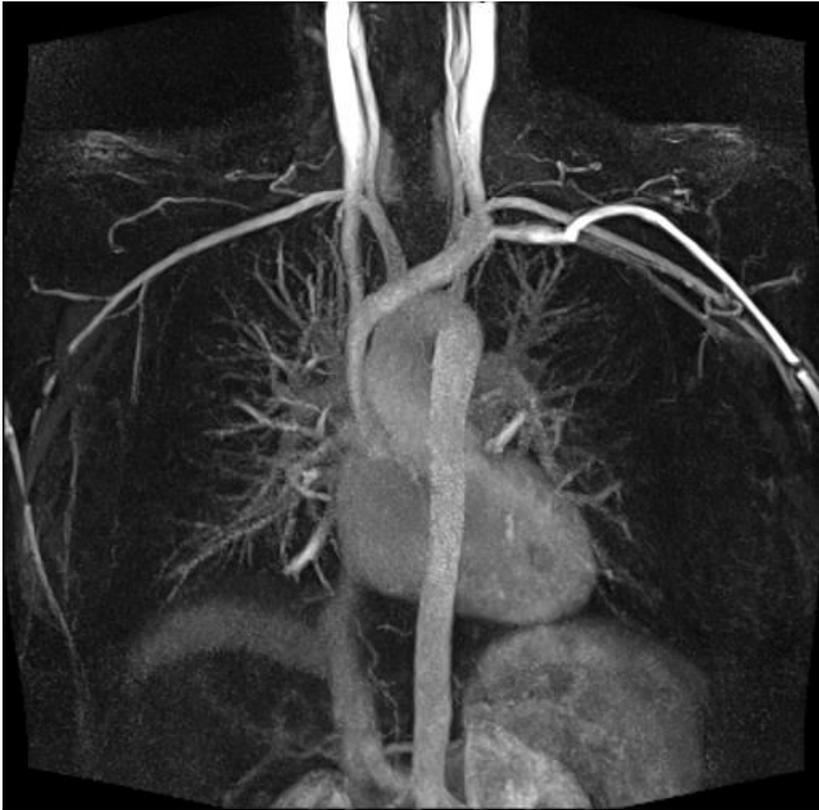
- Type of anatomical imaging that focuses on blood vessels
- Different from ordinary anatomical imaging in its methods to allow discrimination of blood vessels from stationary tissues



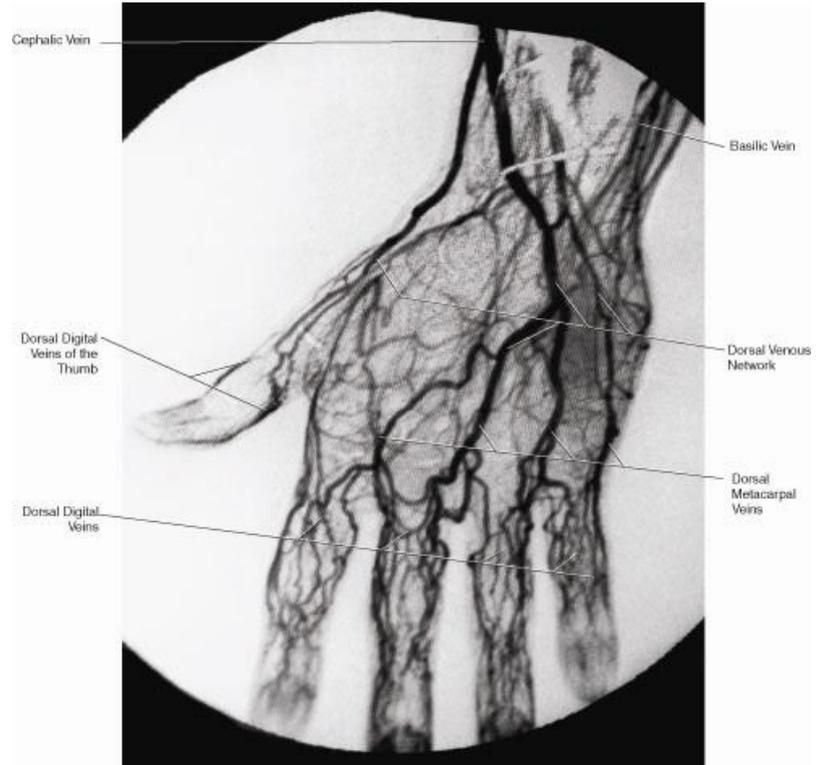
Angiography: Head and Neck



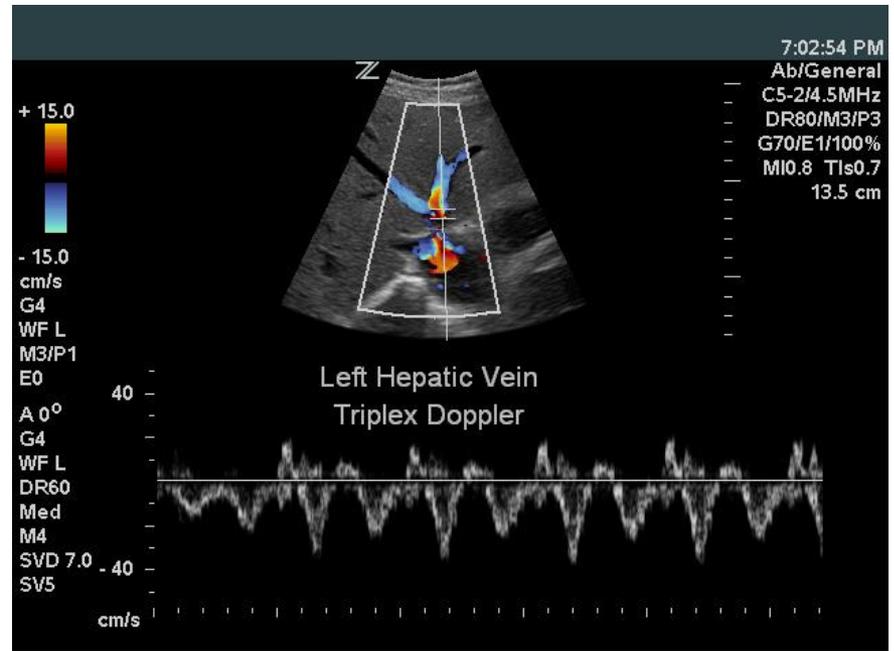
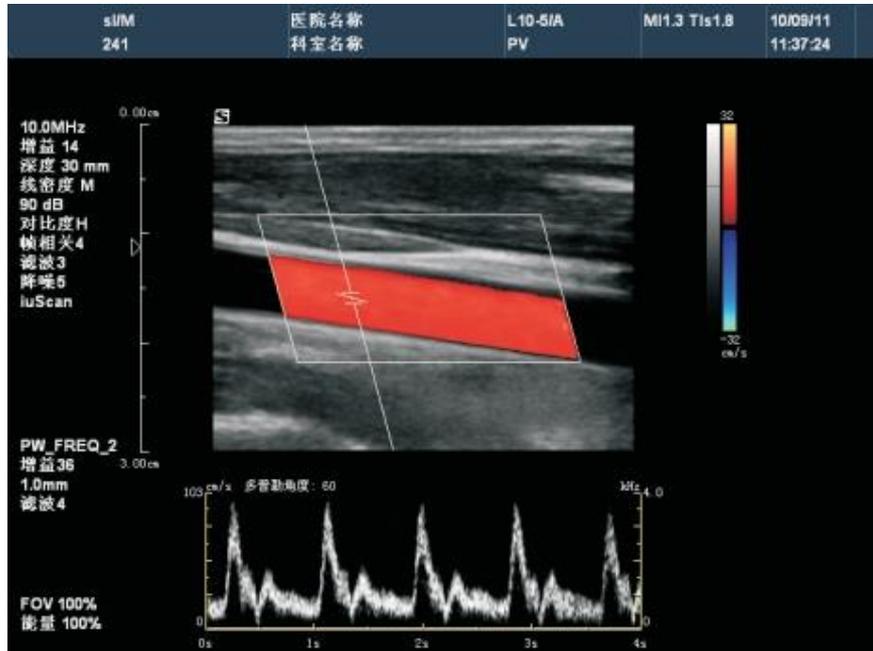
Angiography: Heart and Lungs



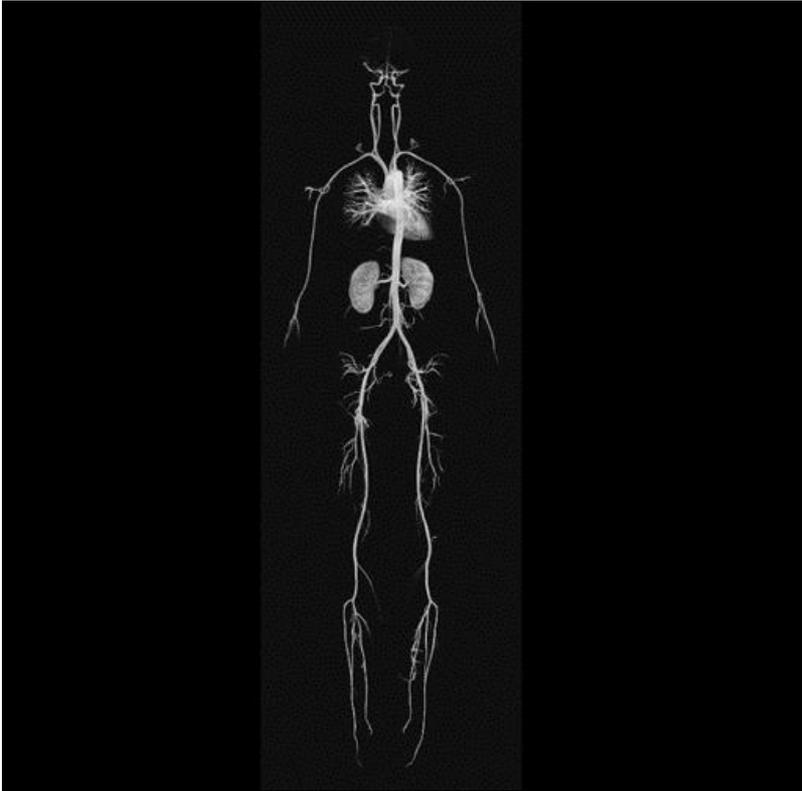
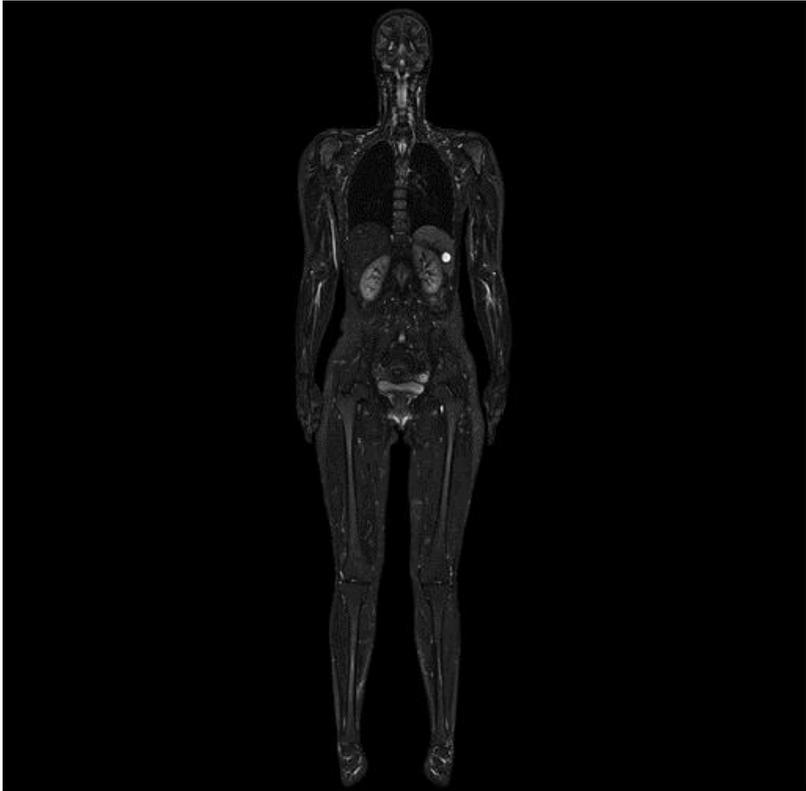
Angiography: Extremities



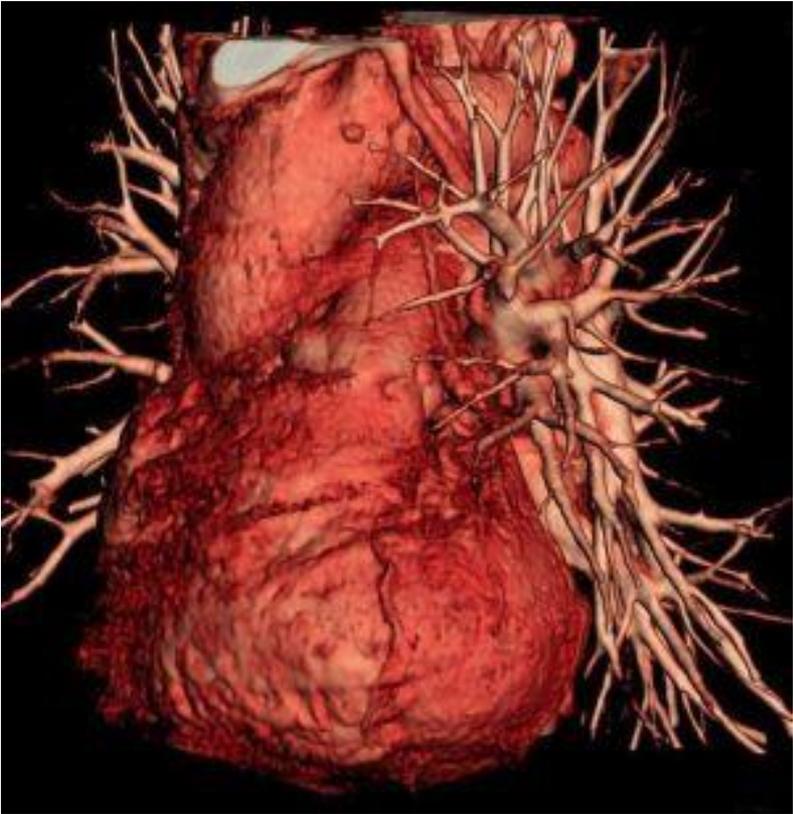
Angiography: Quantitative Assessment



Angiography: Full-Body Scan

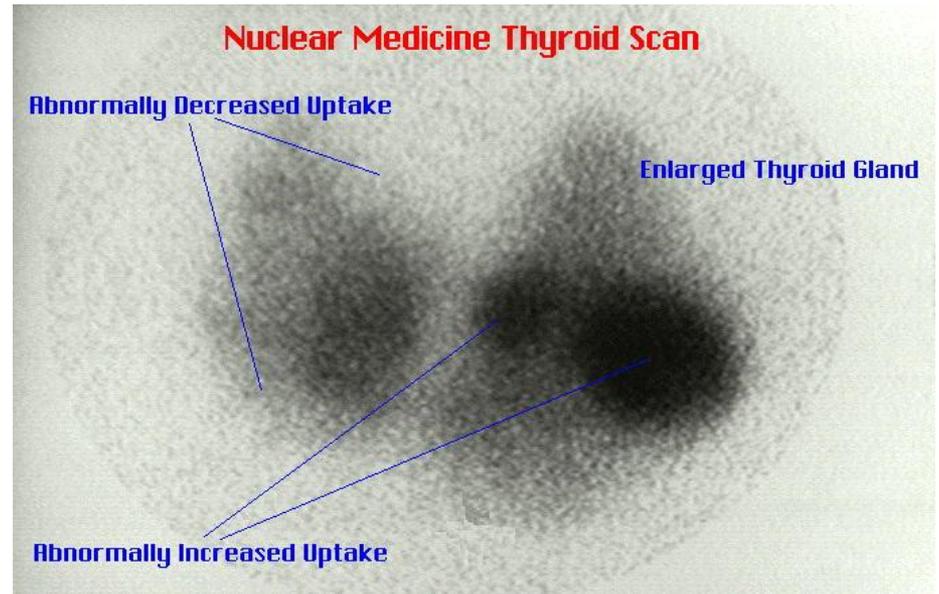
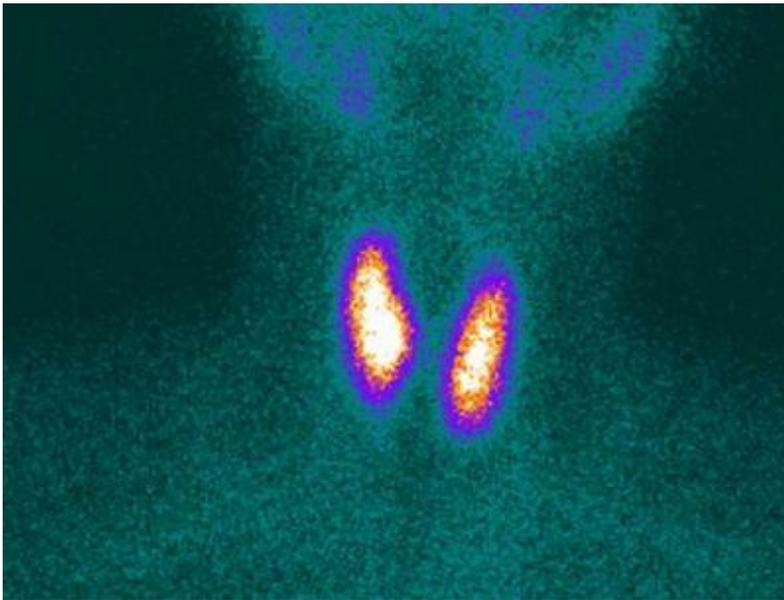


Angiography: 3D

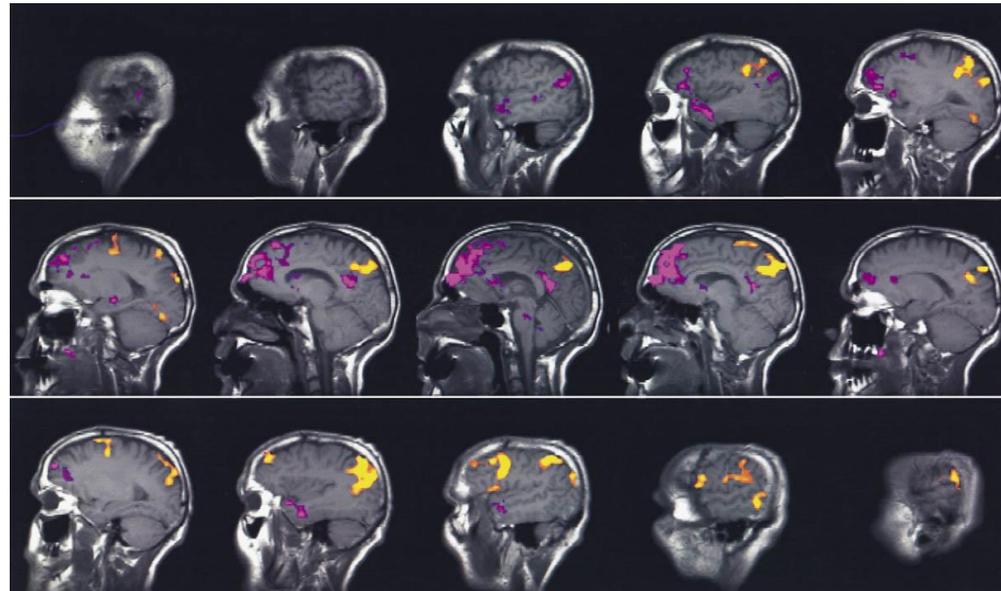
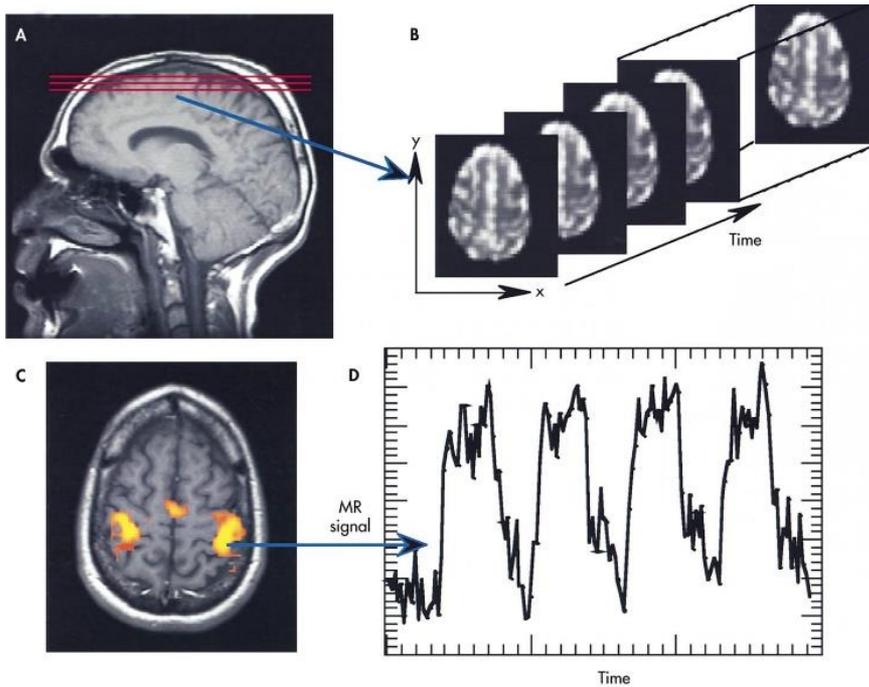


Functional Imaging

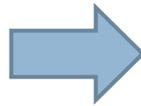
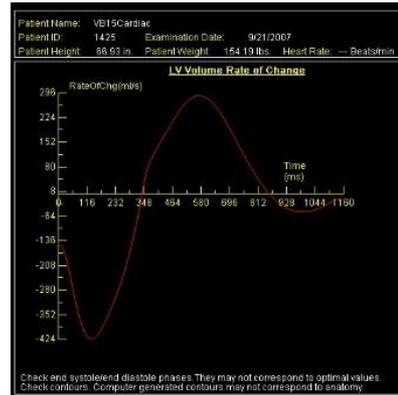
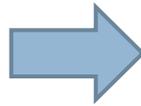
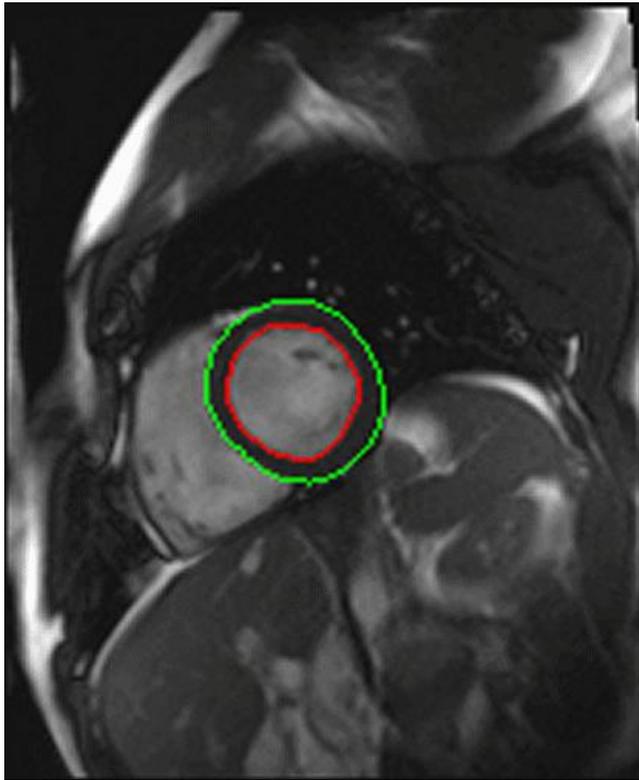
- Image of physiological activity of an organ
 - ▣ Example: Thyroid functional imaging depending on Iodine uptake



Functional Imaging: Brain



Functional Imaging: Heart



Left Ventricular Function

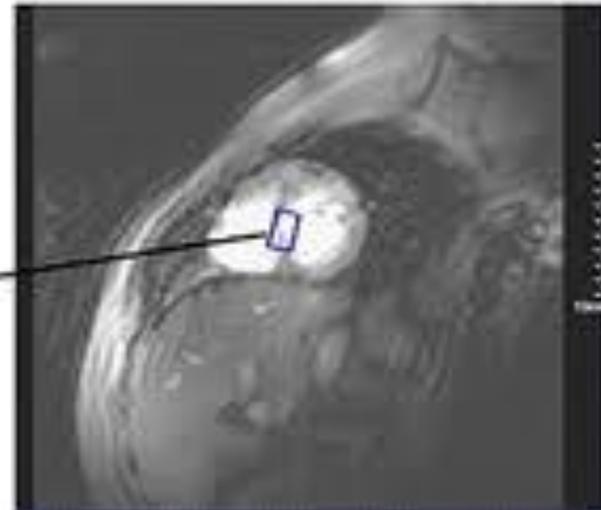
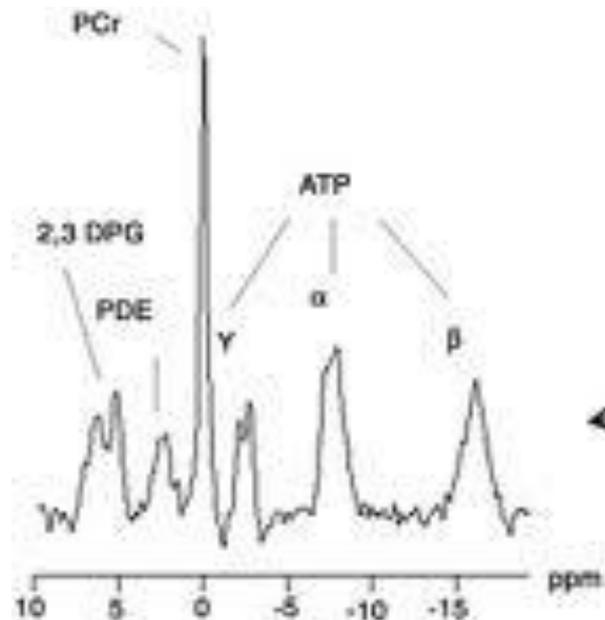
		Absolute	Normalized*
Ejection Fraction	EF	63 %	
End Diastolic Volume	EDV	161 ml	89 ml/m ²
End Systolic Volume	ESV	80 ml	33 ml/m ²
Stroke Volume	SV	101 ml	56 ml/m ²
Cardiac Output	CO	5.0 l/min	
Cardiac Index	CI		2.8 l/min/m ²
Average Heart Rate	HR	50 bpm	
*Normalized to patient surface area		1.8 m ²	
Patient height		1.70 m	
Patient weight		70 kg	

Check ED & ES. Computer estimated ED & ES settings may not be accurate.
 Check contours. Computer generated contours may not correspond to anatomy.

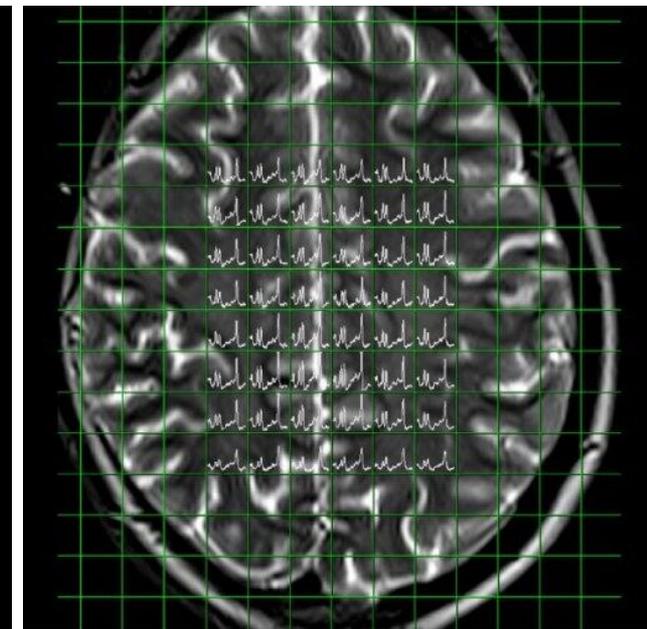
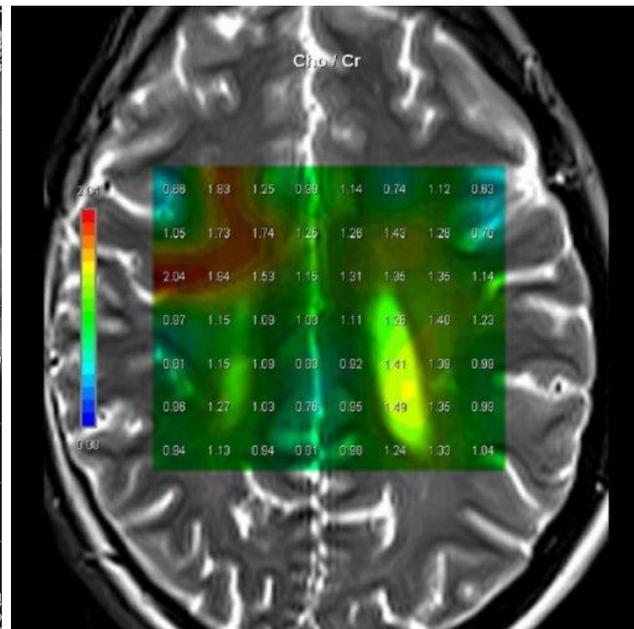
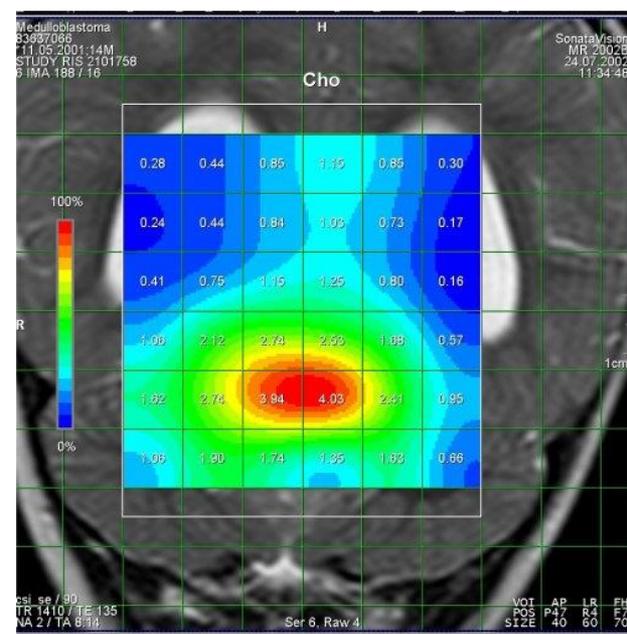


Spectroscopic Imaging

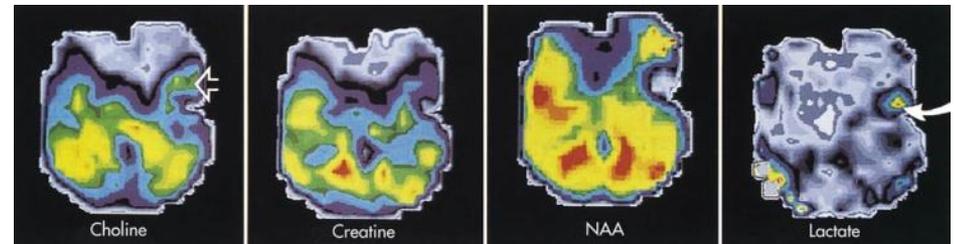
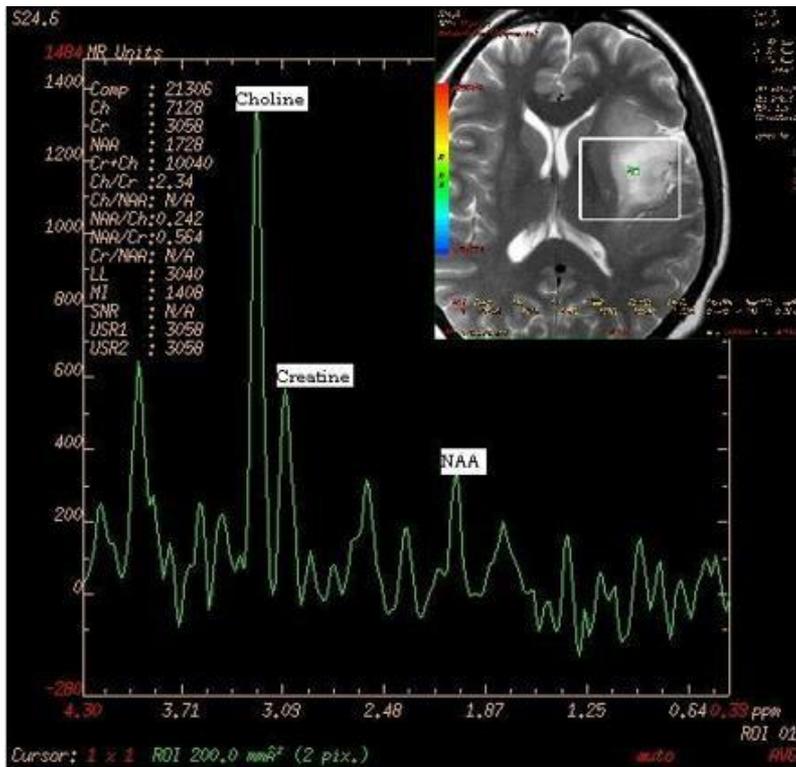
- Mapping of concentrations of certain chemical compounds inside the body



Spectroscopic Imaging: Brain

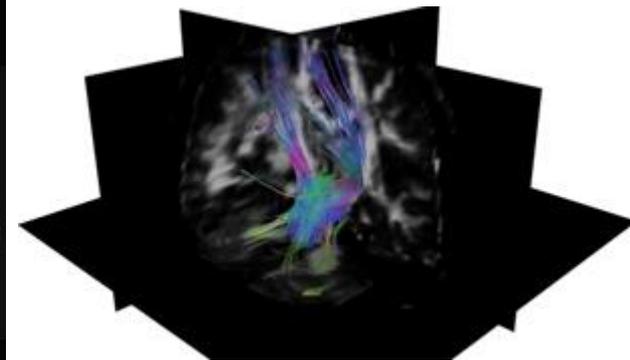
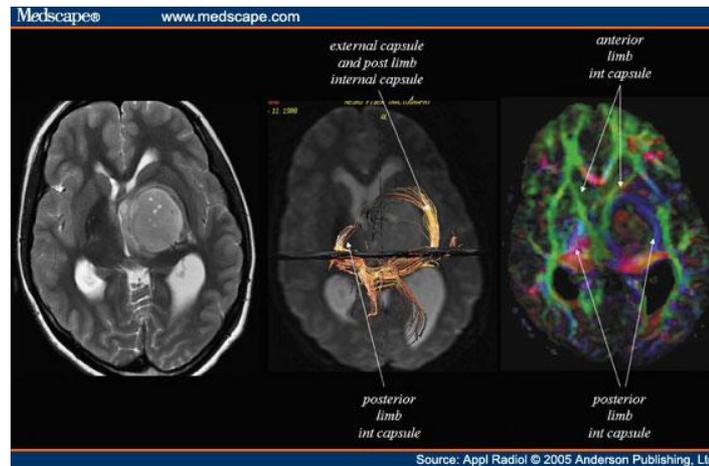
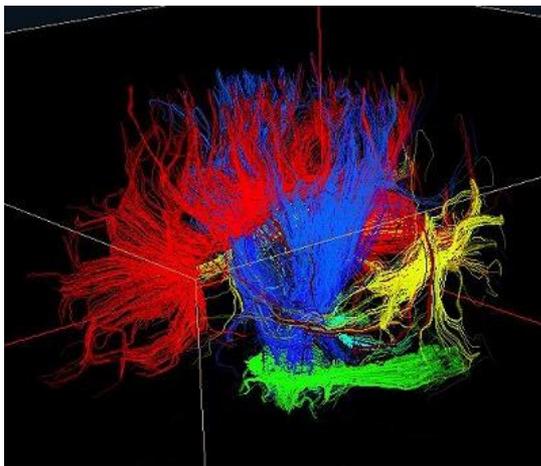


Spectroscopic Imaging: Virtual Biopsy



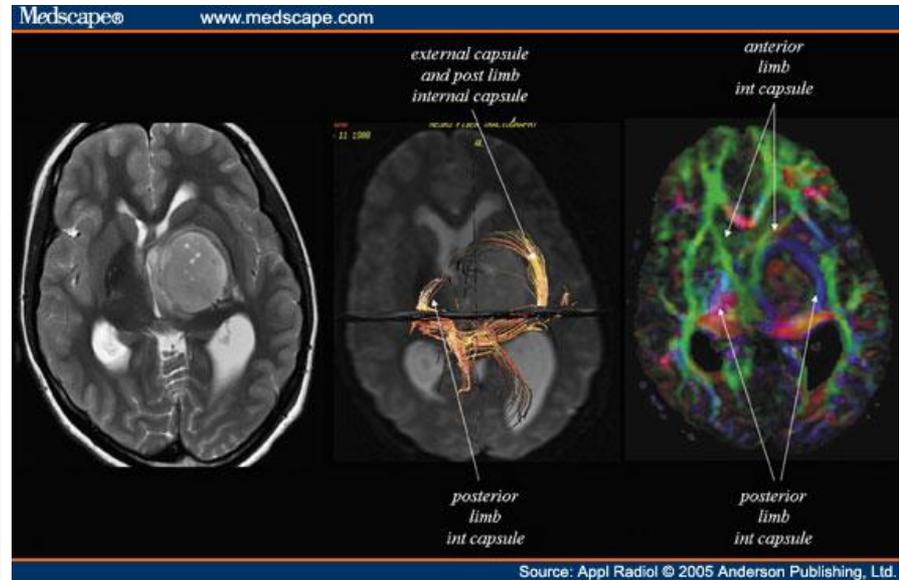
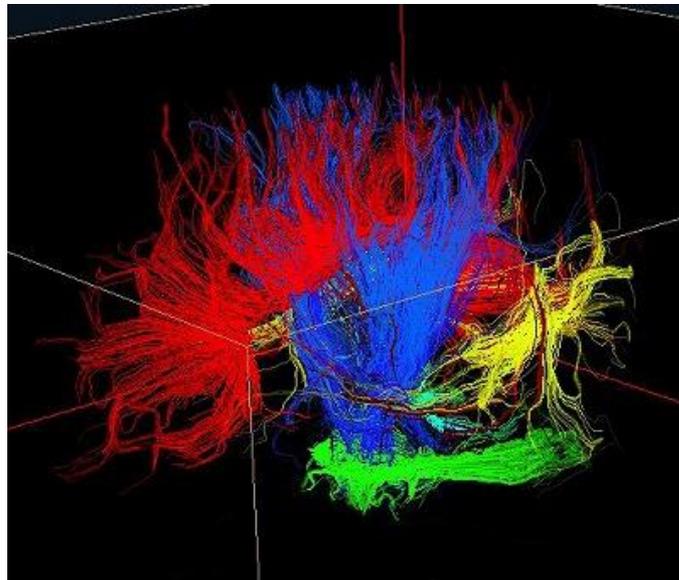
Connectivity Imaging

- Mapping of physical routes between different locations in the brain and correlation with their functions



Connectivity Imaging: Physical

- Mapping of brain “wiring”



Connectivity Imaging: Functional

- Detection of brain areas that work together on certain functions

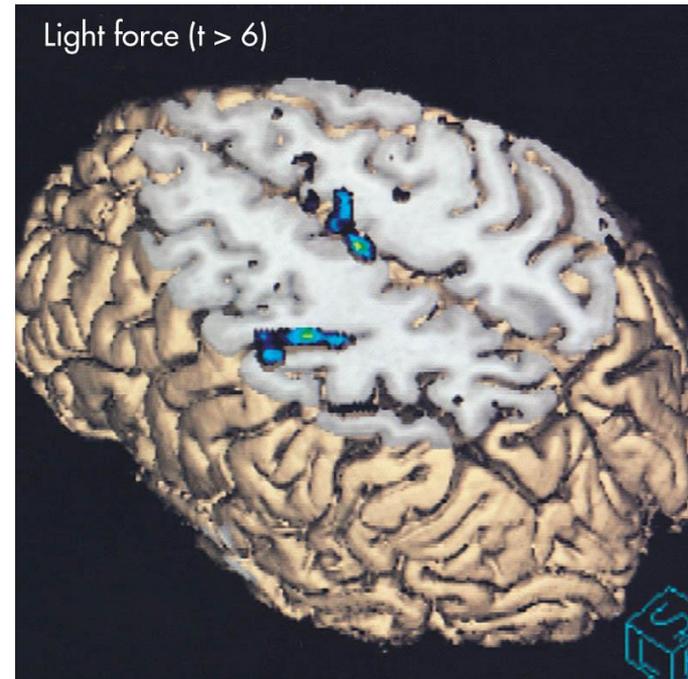
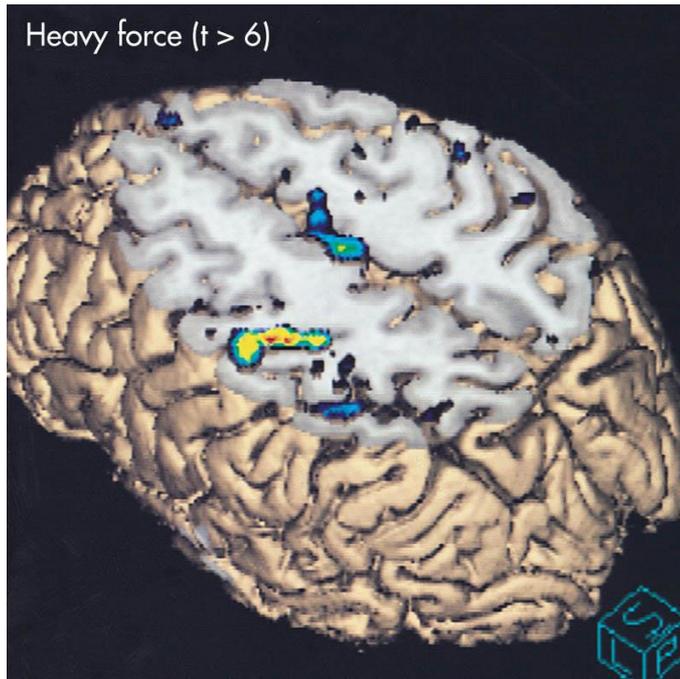


Image Guided Surgery: Planning

- Using 3D model of the surgical location, surgeon can study alternatives before surgery to choose most effective

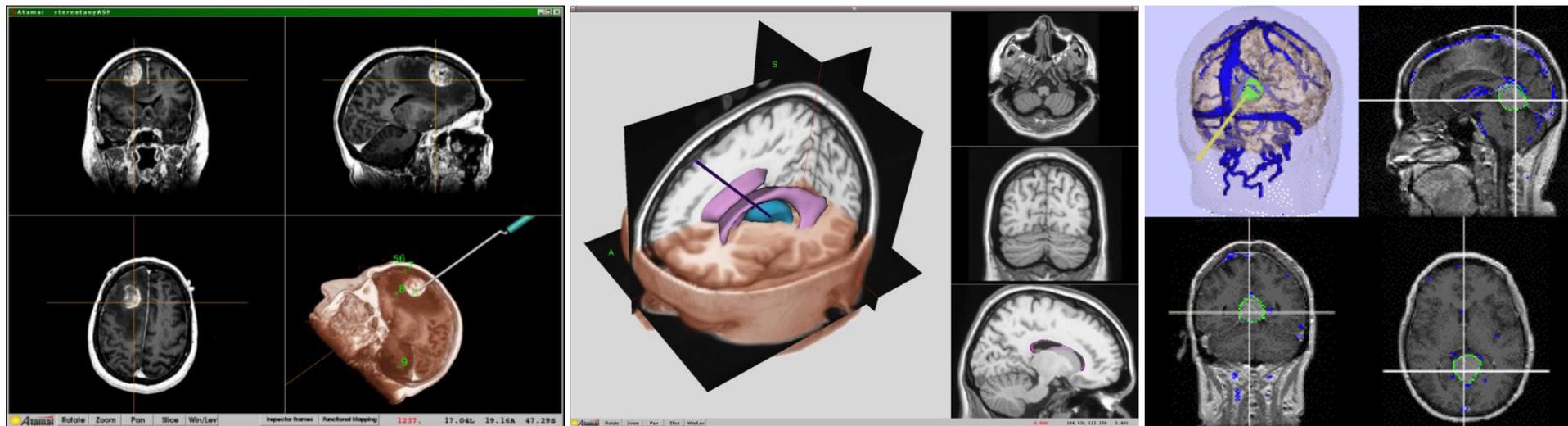


Image Guided Surgery: Interventional

- Medical imaging systems designed for surgical interventions



Image Guided Surgery: Biopsy

- Imaging of needle to accurately collect biopsy

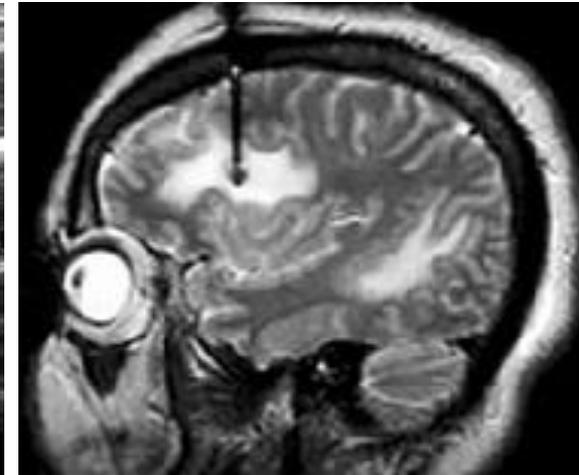
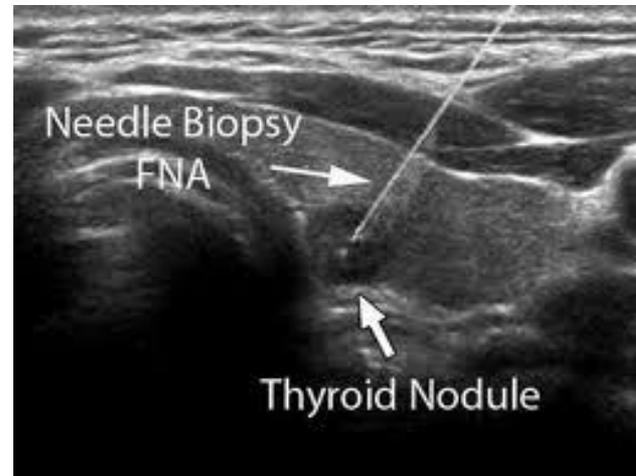
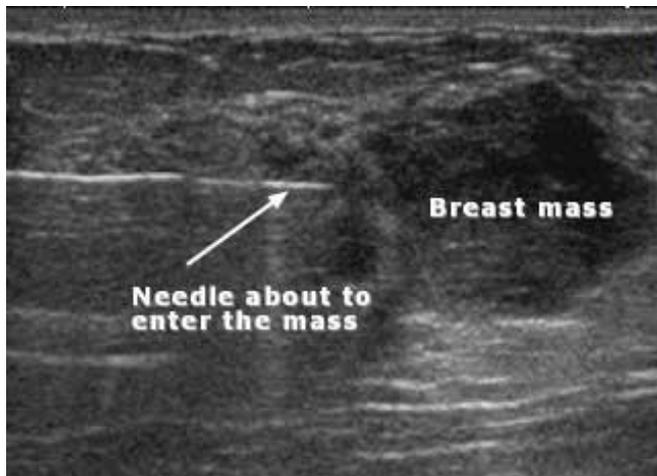


Image Guided Tissue Engineering: Planning

- Computer models used to simulate different strategies *in silico*
 - ▣ Finite element modeling

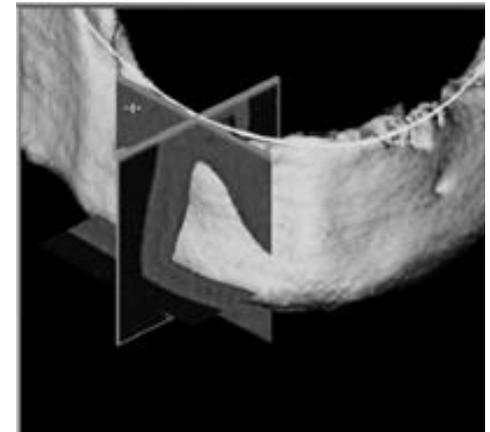
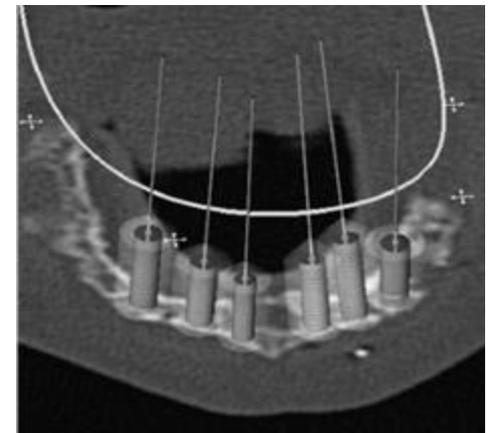
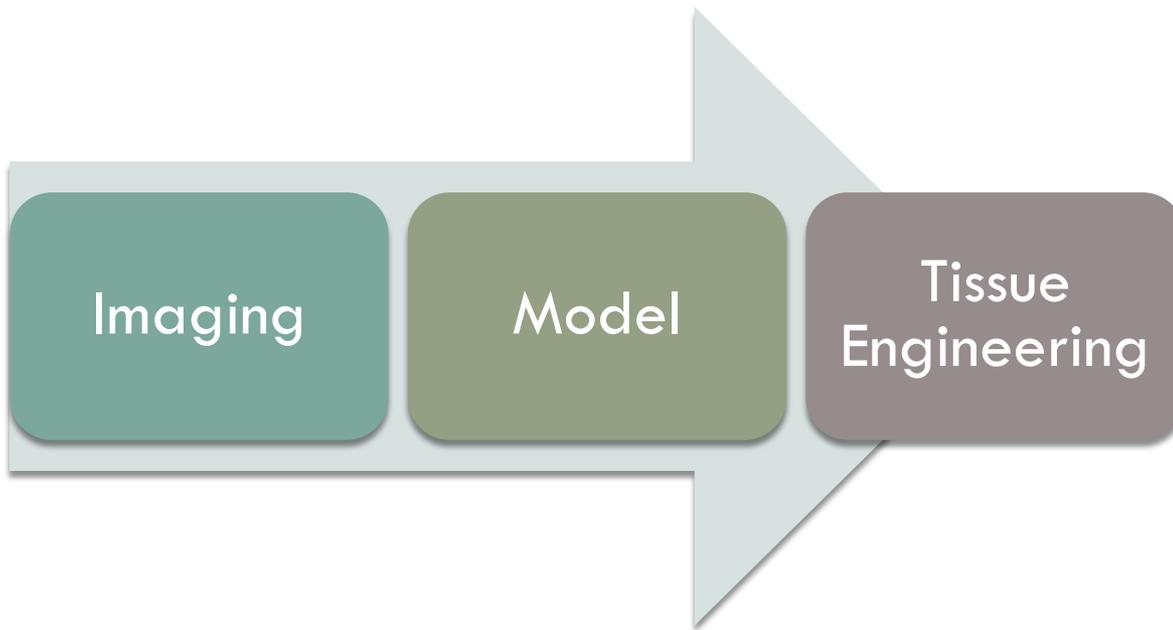


Image Guided Tissue Engineering: Design

- Design of scaffold or implant using data from imaging
 - ▣ Accounts for complex patient-specific geometry
 - ▣ CAD/CAM methods

Imaging

Scaffold
Design

Tissue
Engineering

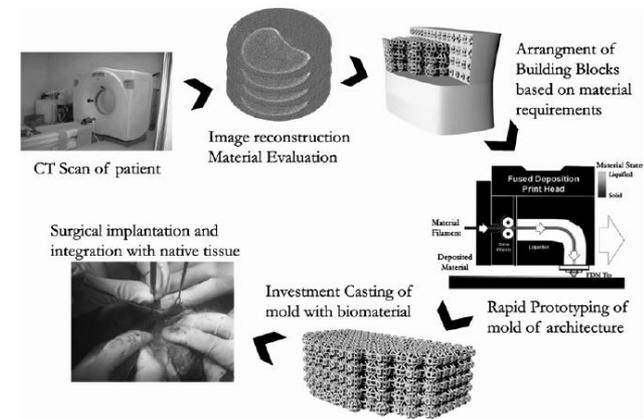


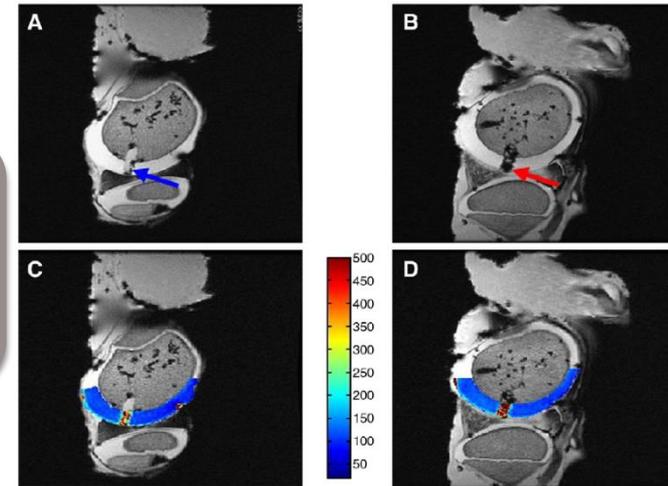
Image Guided Tissue Engineering: Assessment

- Follow up on progress of procedure to assess its stage of development and/or integration
 - ▣ Example: labeling of mesenchymal stem in cartilage tissue engineering

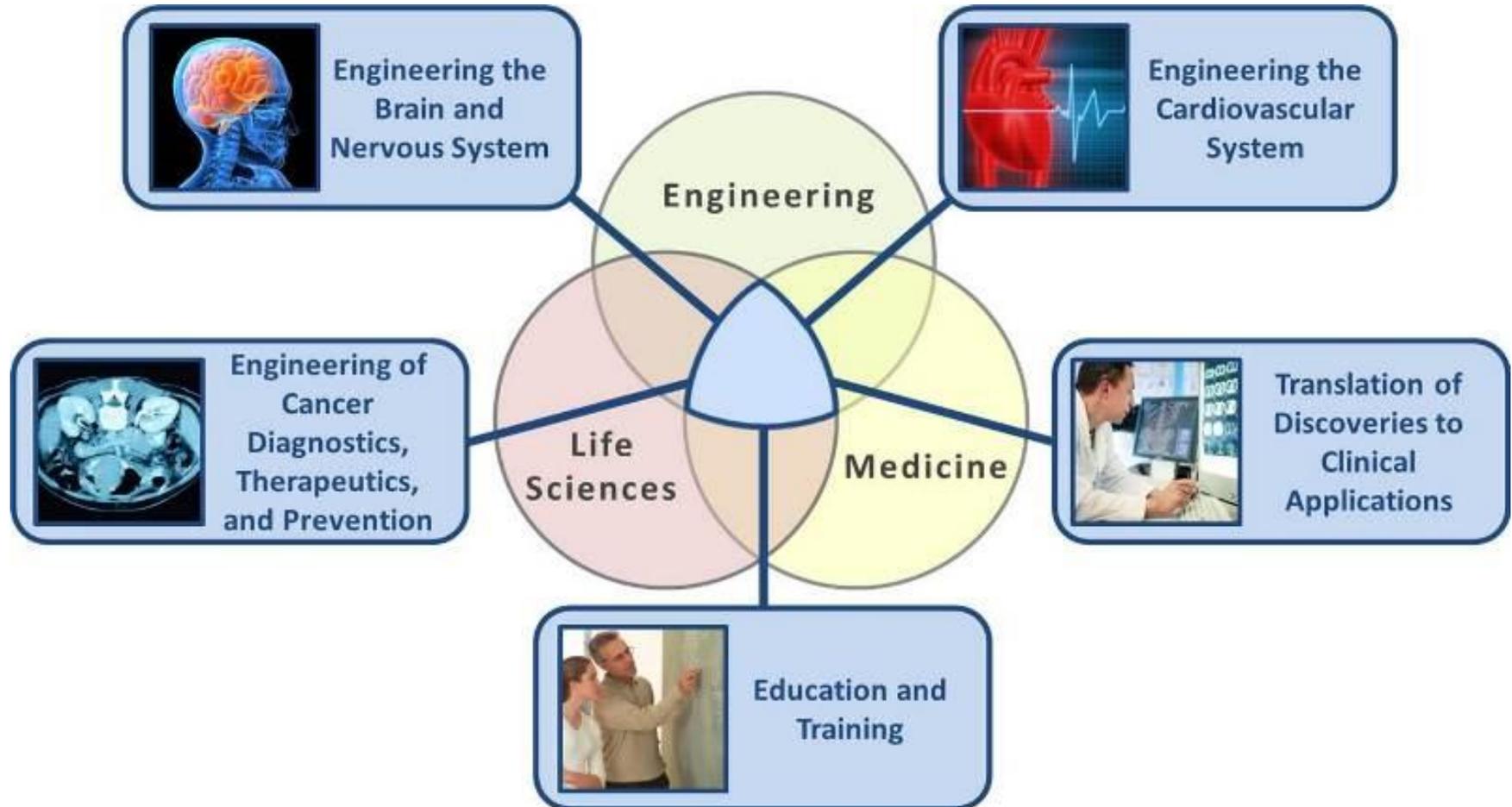
Tissue
Engineering

Imaging

Progress
Assessment



Biomedical Engineering Frontiers



Concluding Lessons from History

- New applications of existing technologies in other fields
- New technologies that allow use of existing theory in physics or mathematics
- Come from academia or industry and from scientists of any discipline (engineers, doctors, physicists, etc.)
- Introduction of new technology sometimes meets significant resistance
- Safety should not be overlooked in any new technology
- Every technology has its advantages and limitations
 - ▣ People focus on advantages first then realize limitations later
- New technology *Time-to-Market* is usually long but critical
 - ▣ Require multidisciplinary team to develop

Further Reading and Assignments

- Chapter 1 of *Introduction to Biomedical Engineering*
- Chapter 1 of *Springer Handbook of Medical Technology*

- Assignment on class web site