
# BIOMEDICAL ENGINEERING: HISTORICAL PERSPECTIVES AND PRESENT STATUS



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# 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

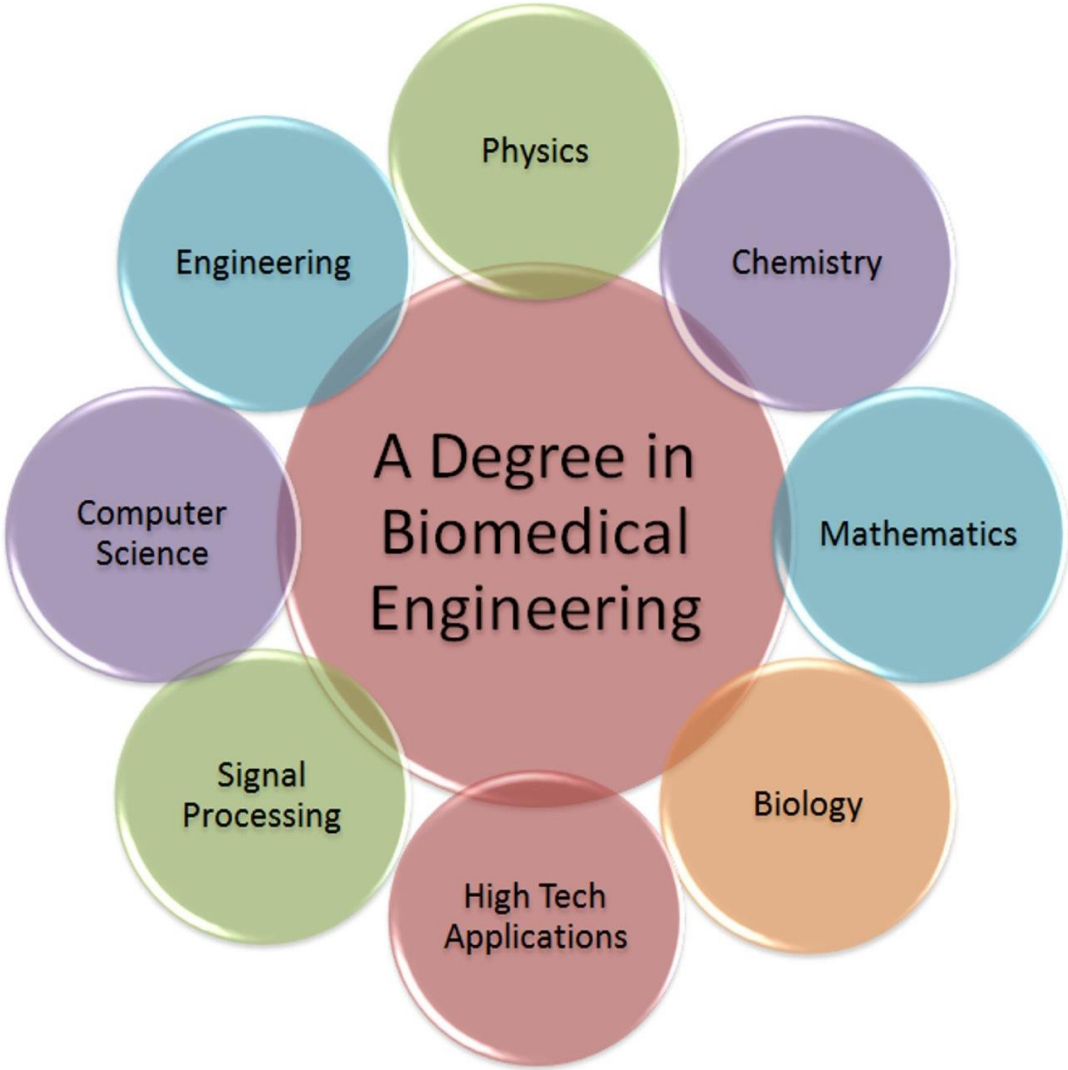
# Role of Biomedical Engineering

- 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

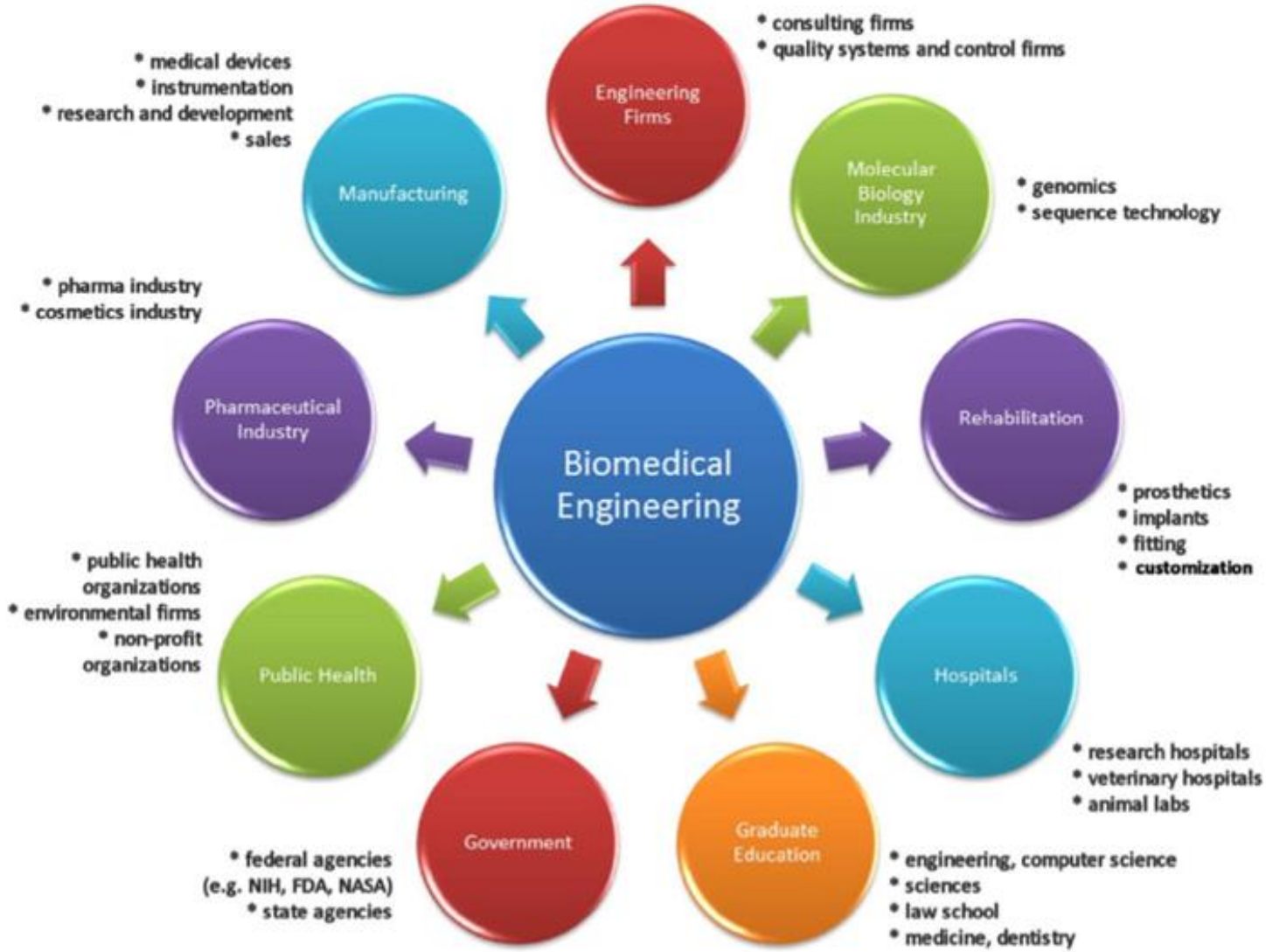
- Role summary: *provide tools and solve medical technology problems*

# Components of Biomedical Engineering

- Graduate:
  - Bioengineer
  - Biomedical Engineer
  - Biological Engineer
  - Medical Engineer
  - Clinical Engineer



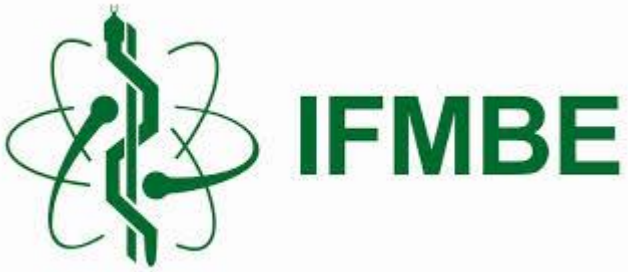
# Biomedical Engineering Employment



# Example Professional Societies

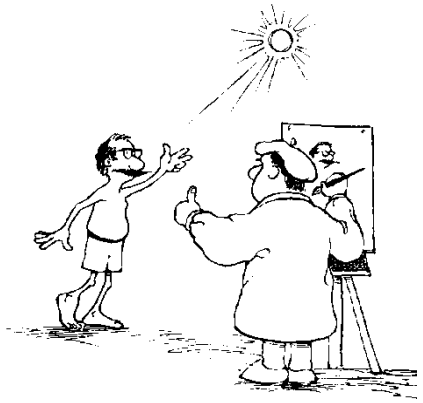
- Association for the Advancement of Medical Instrumentation (AAMI)
- IEEE Engineering in Medicine and Biology Society (IEEE EMBS)
- International Federation for Medical & Biological Engineering (IFBME)
- Biomedical Engineering Society (BMES)
- Saudi Scientific Society of Biomedical Engineering (SSSBE)

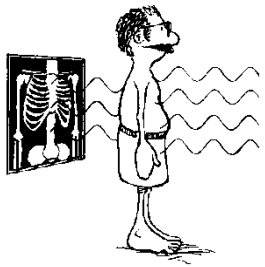


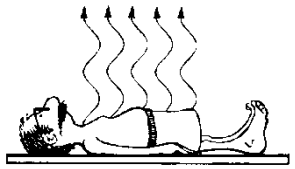



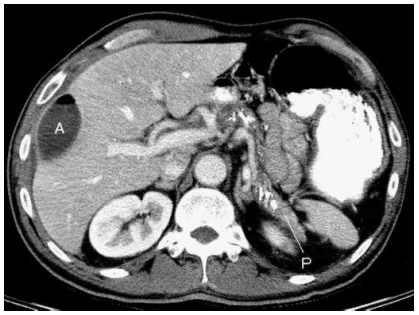

# History Example: Medical Imaging

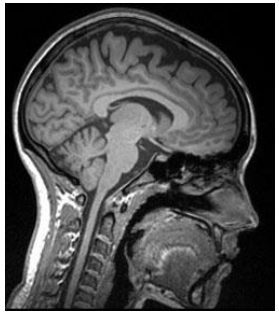
- Methodology to measure and map a useful property of human tissues
- Non-invasive or minimally-invasive
- Examples:
  - Reflection – photography, ultrasound
  - Transmission – x-rays
  - Radiation – MRI, PET/SPECT









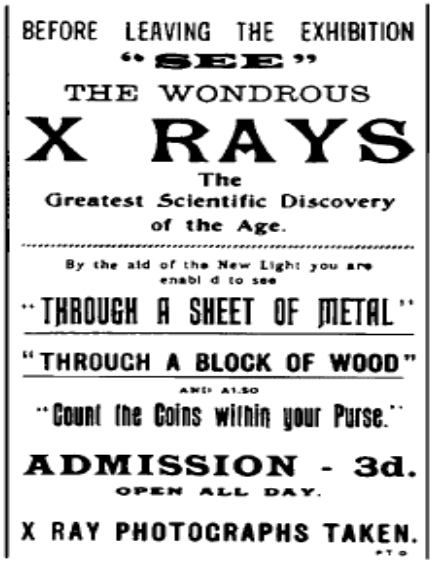



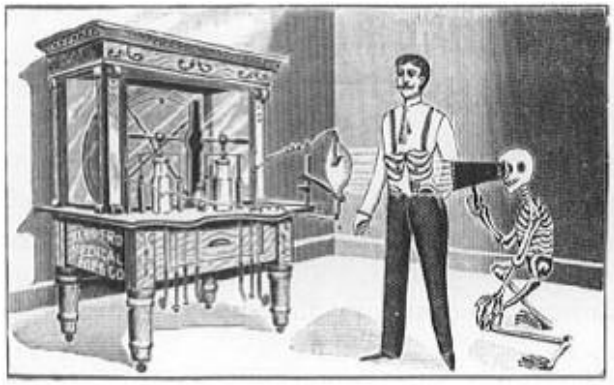
# History of Medical Imaging

- 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

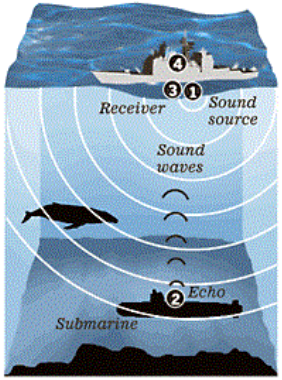
- Start of medical imaging era from discovery of X-rays by Röntgen in 1895



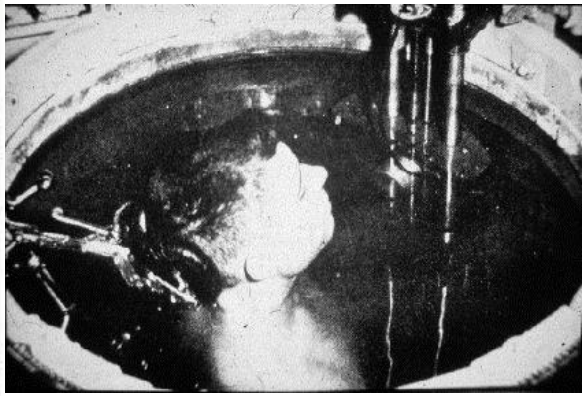



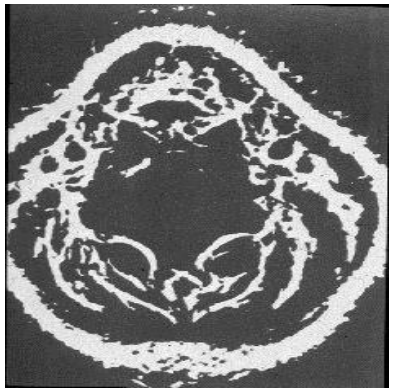

# History of Ultrasound Imaging

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





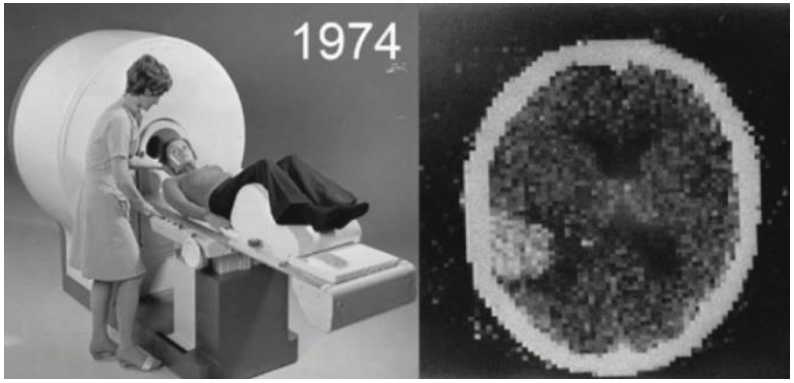




# History of Computed Tomography

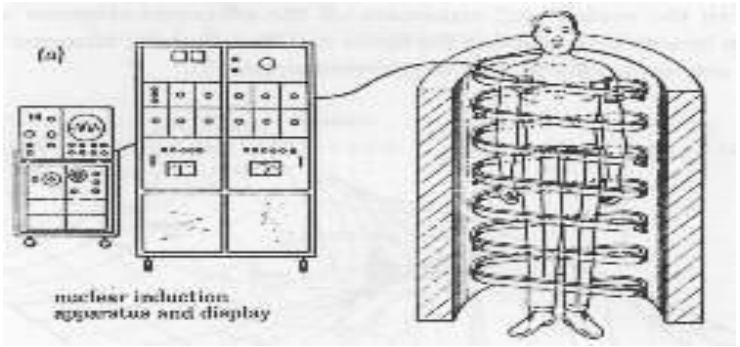
- First developed by Godfrey Hounsfield in 1971
  - Theory of image reconstruction developed in 1924 by Radon

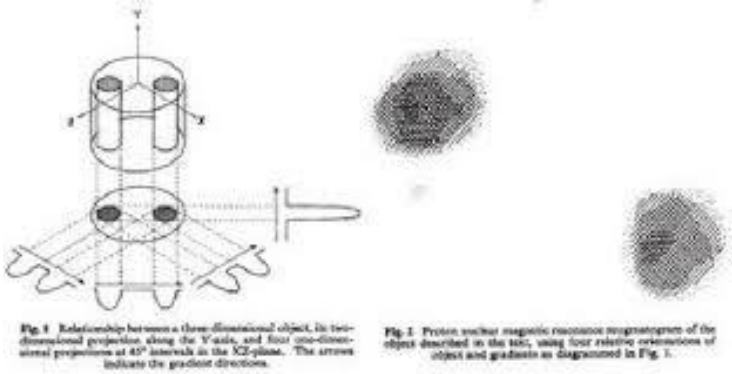





# History of Magnetic Resonance Imaging

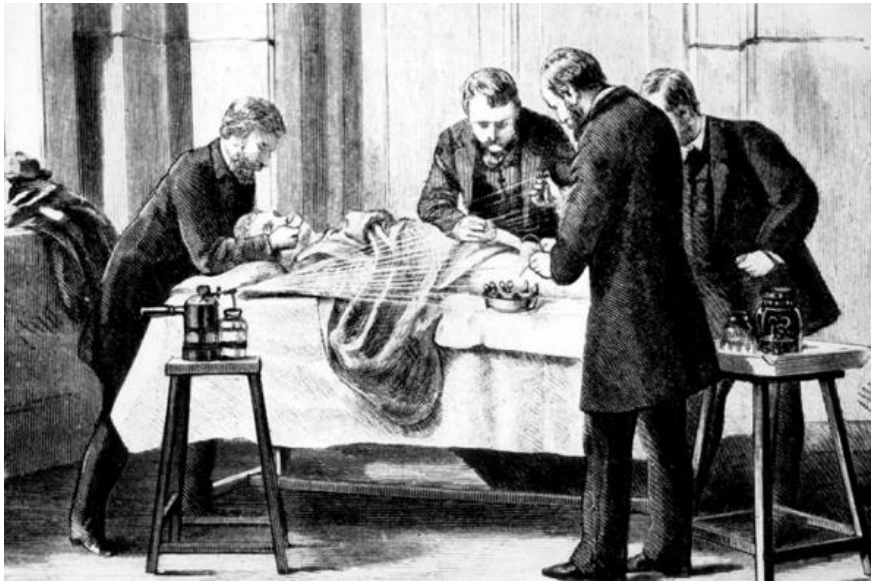
- First recorded images in 1973 by physicist Paul Lauterbur
  - Application of theory independently developed by Bloch and Purcell in 1946



# Now: Role of Imaging

- Reduce surgical interventions intended for diagnosis



19th Century

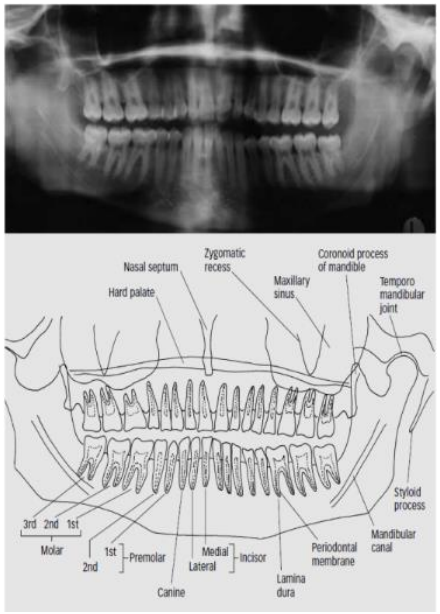
Now

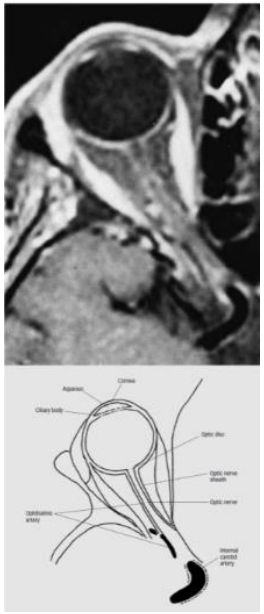
# Anatomical Imaging

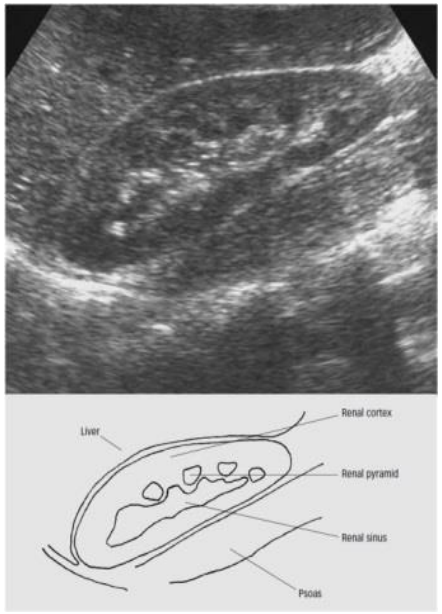
- Collection of images of internal organs to aid diagnosis

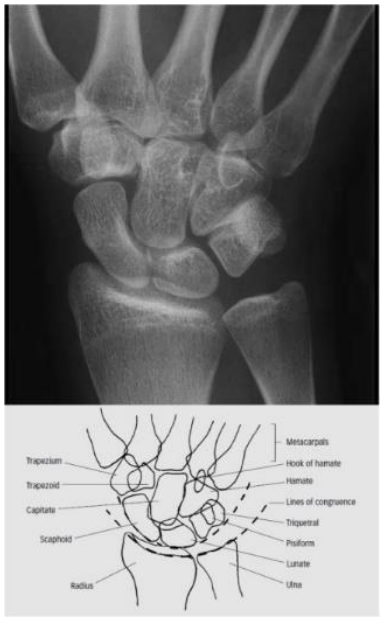
# Anatomical Imaging

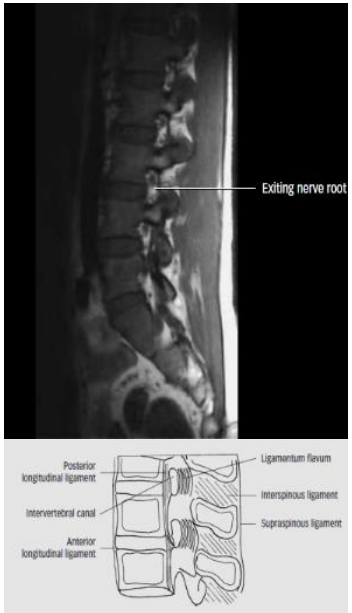
- Examples showing correlation with textbook anatomy



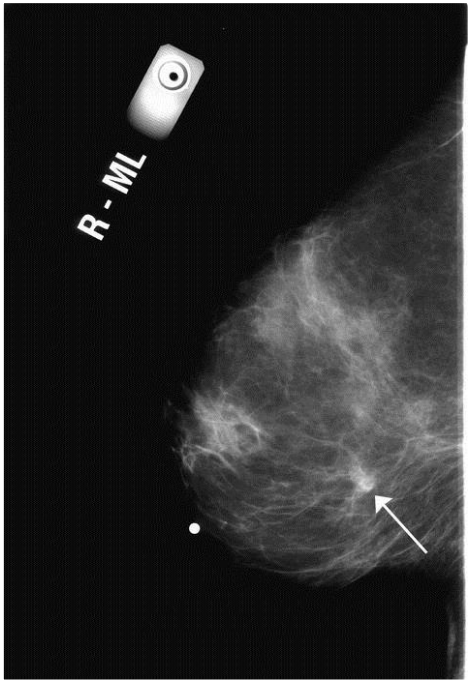





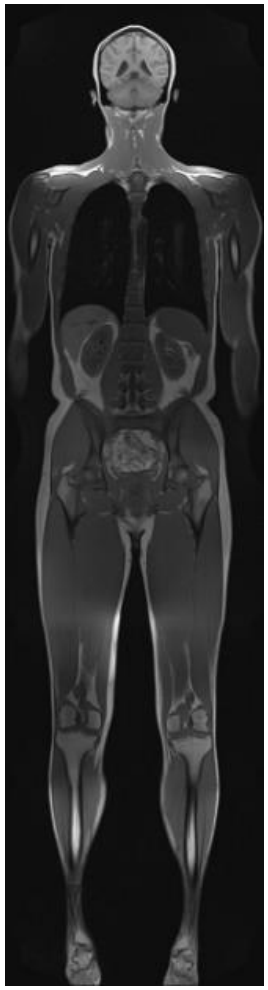



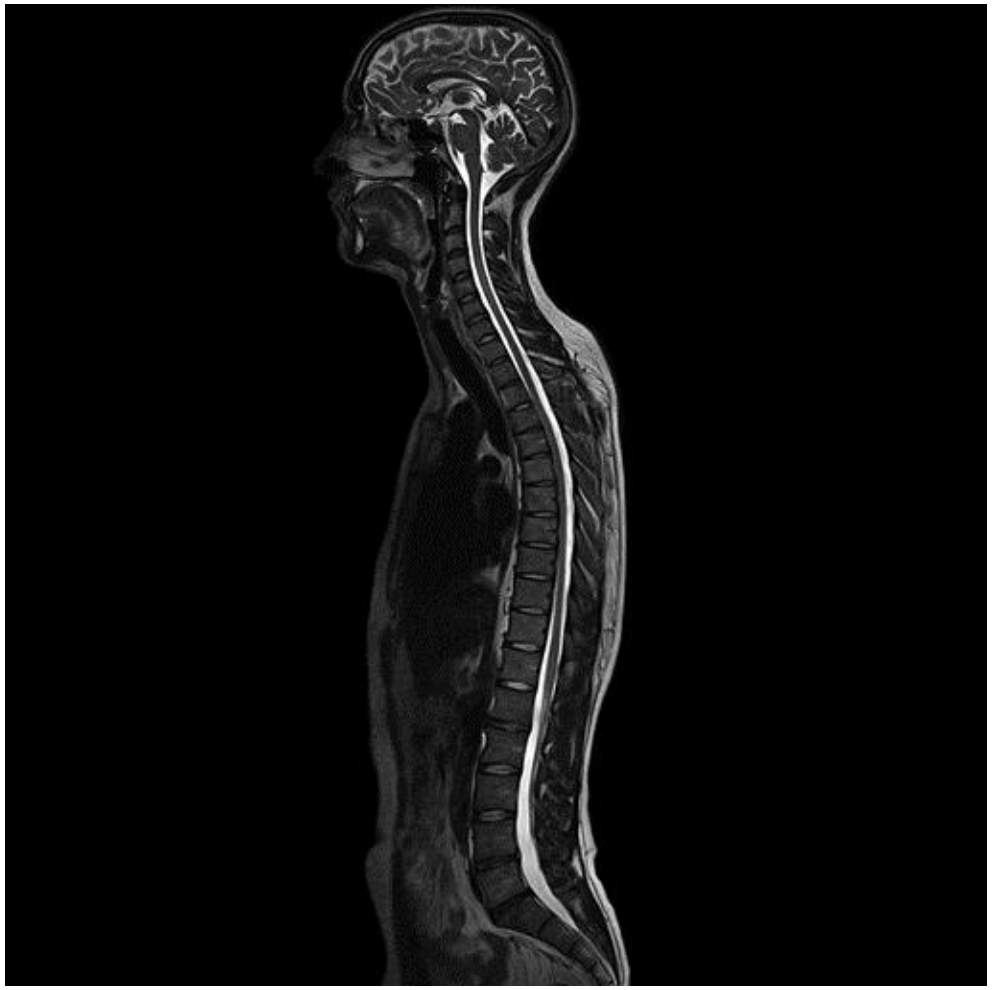



# Anatomical Imaging: Tumor detection

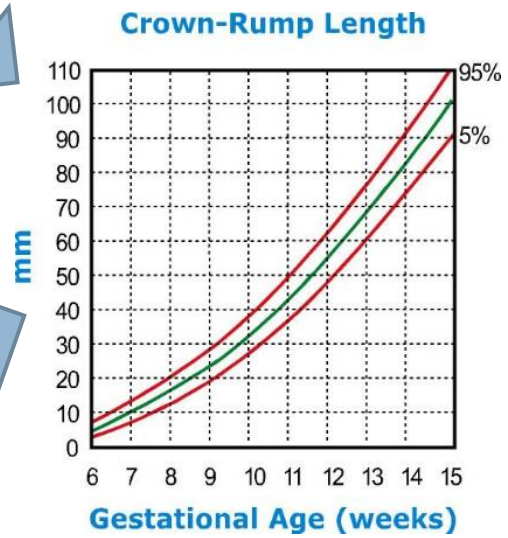



# Anatomical Imaging: Full-Body Scan



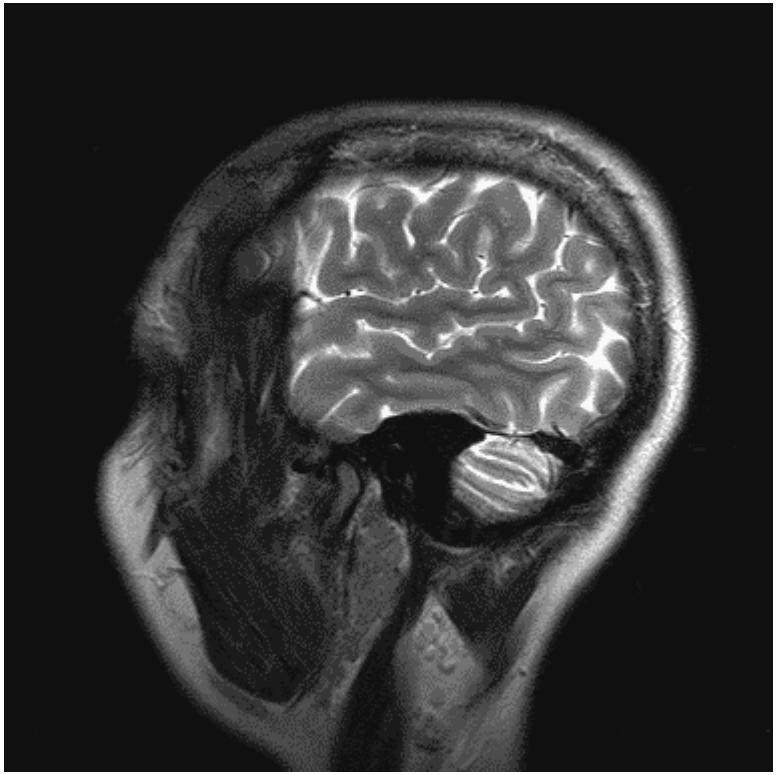


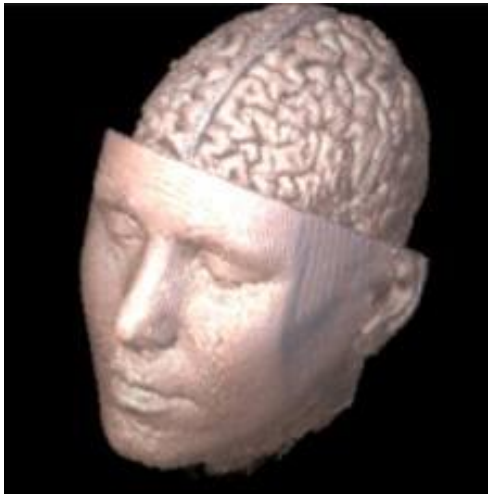
# Fetal Age Calculation From Ultrasound




**Age Estimation**

# 3D Imaging

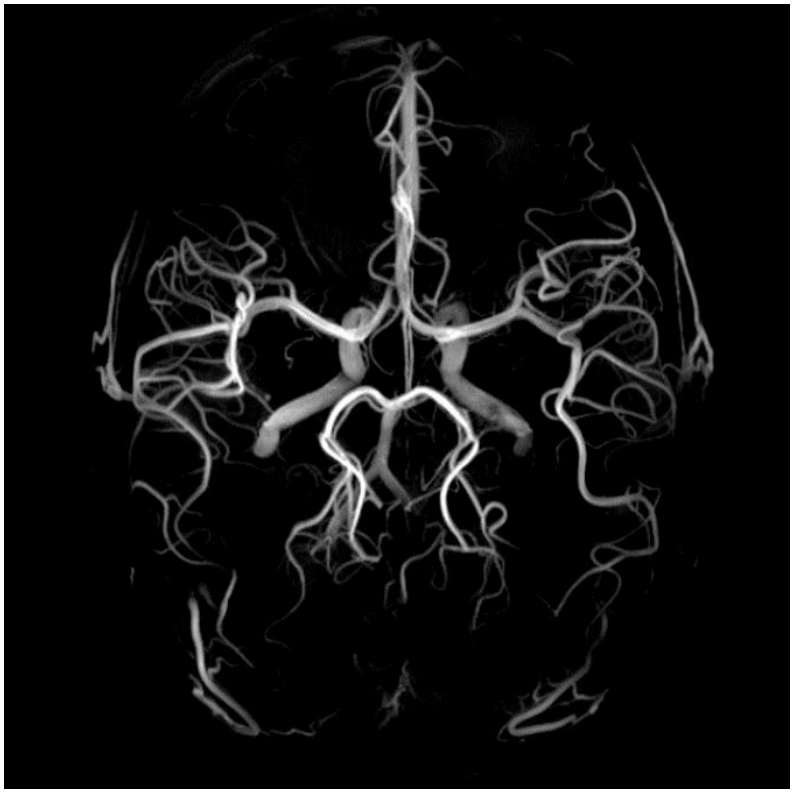




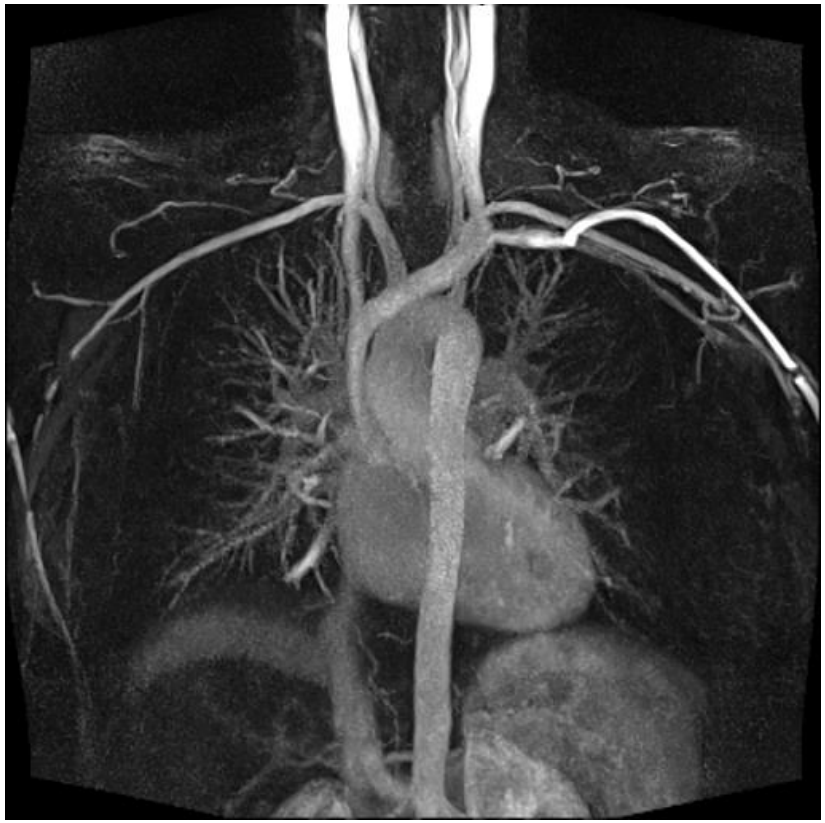
# Angiography

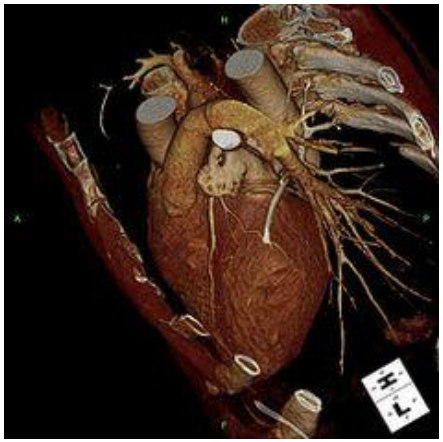
- Type of anatomical imaging that focuses on blood vessels
- Different from ordinary anatomical imaging in its methods to allow discrimination of blood vessels from stationary tissues

# Angiography: Head and Neck

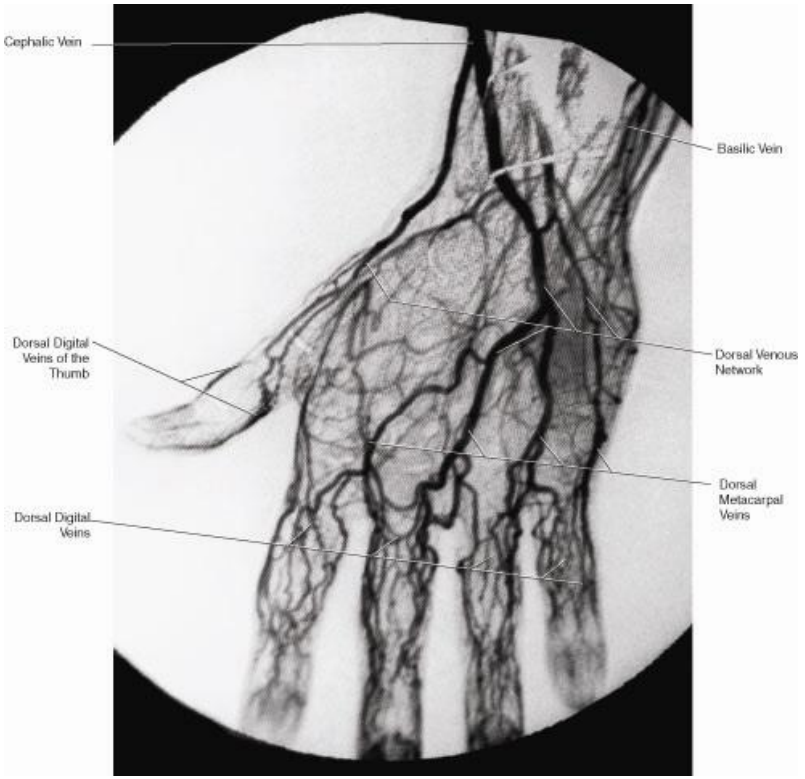


# Angiography: Heart and Lungs

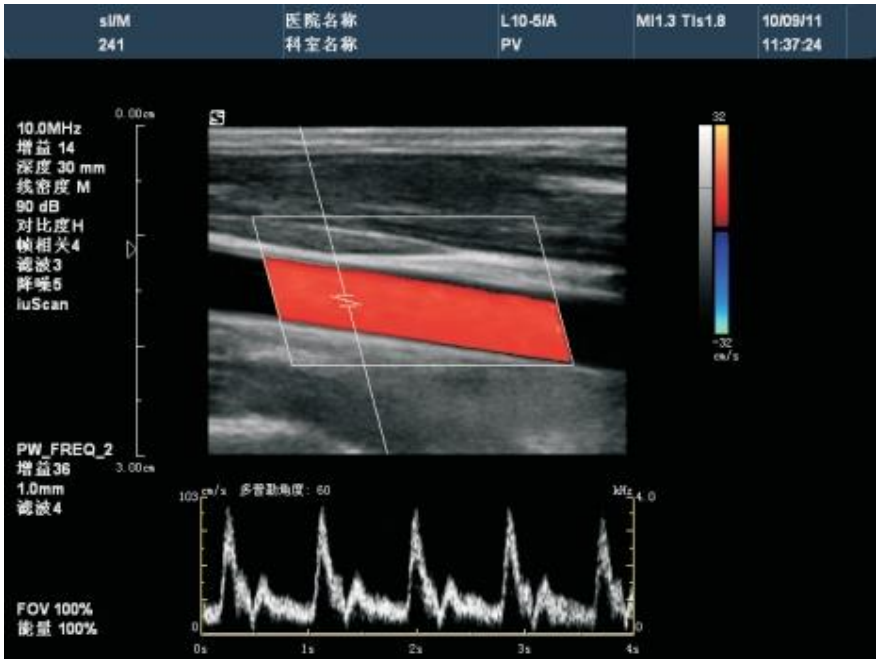


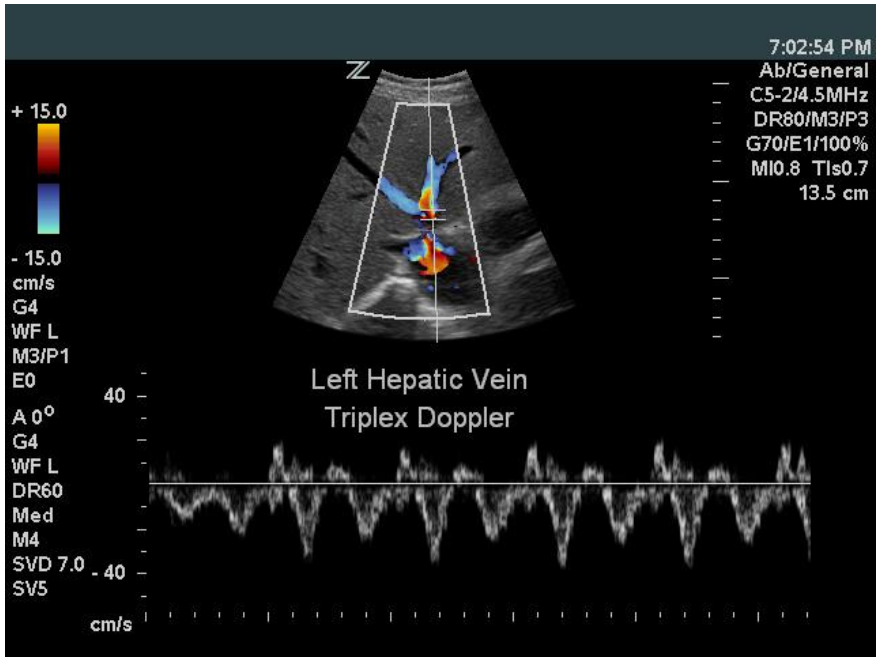


# Angiography: Extremities

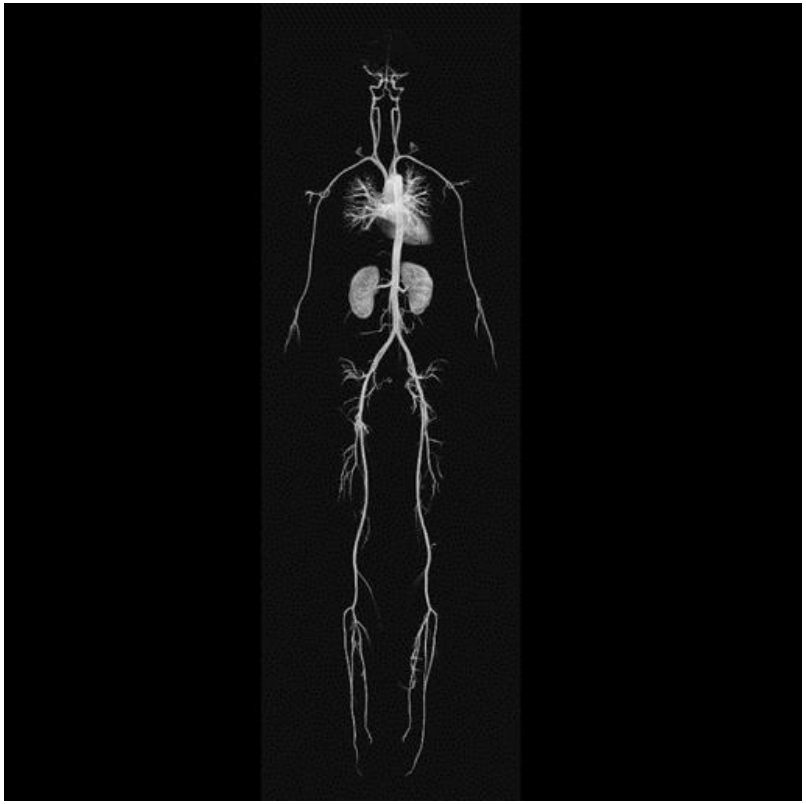



# Angiography: Quantitative Assessment



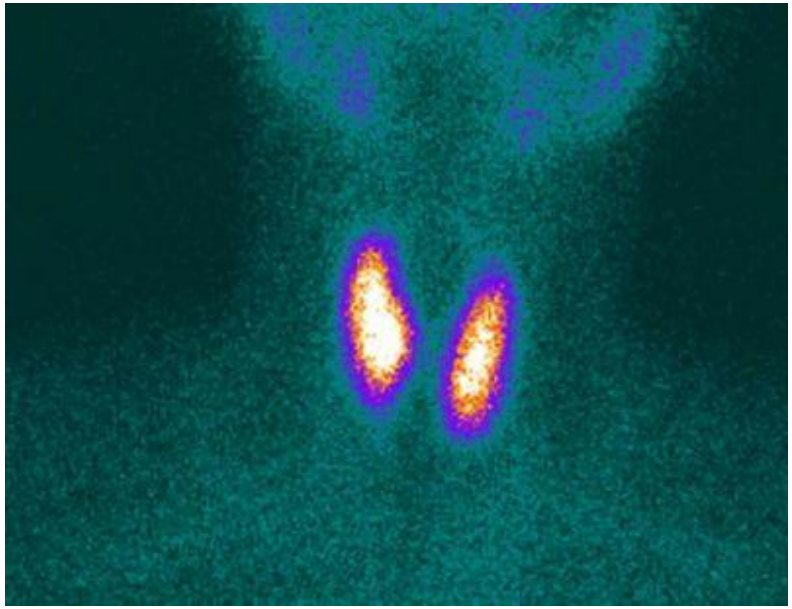
# Angiography: Full-Body Scan

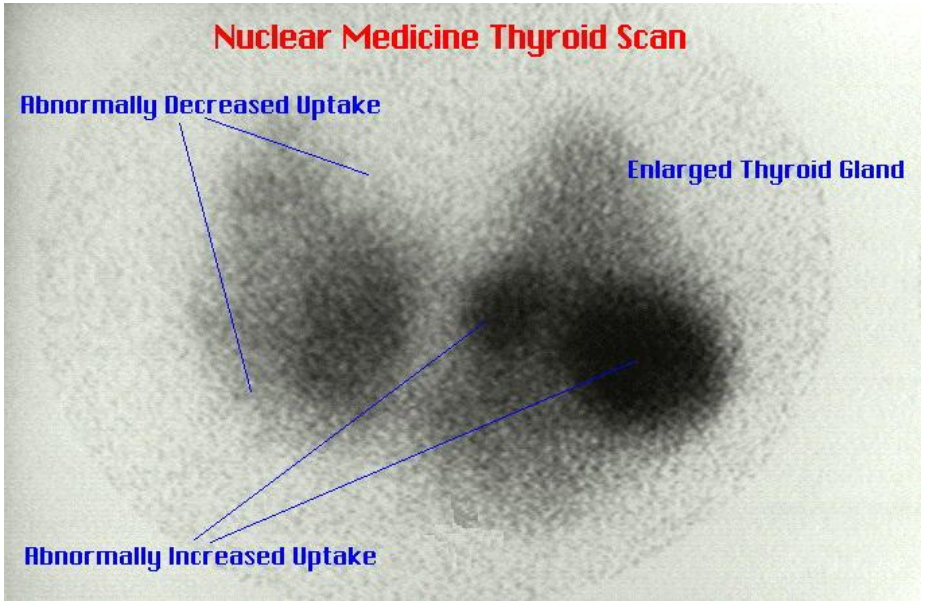


# Angiography: 3D

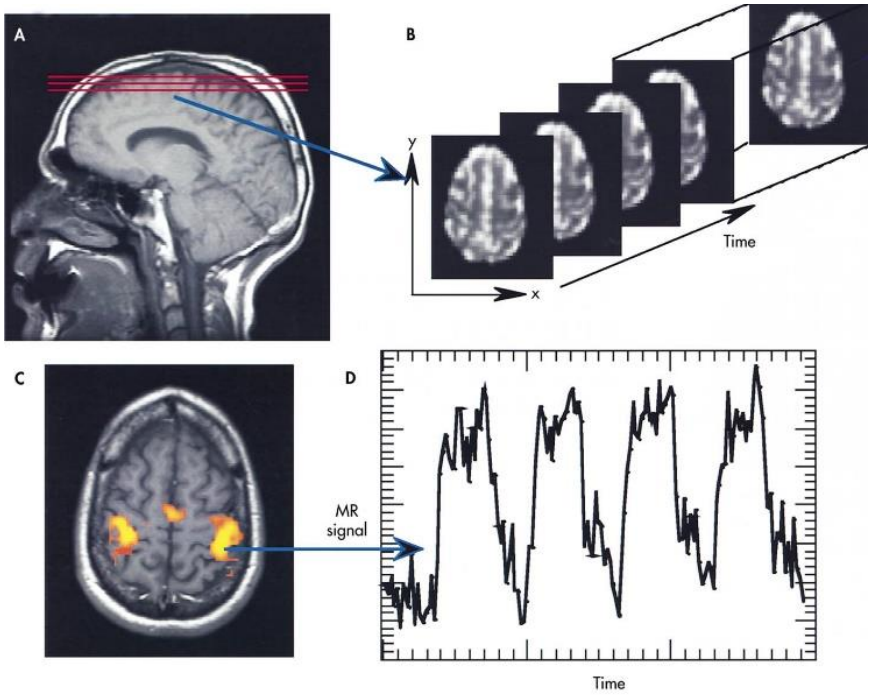
# Functional Imaging

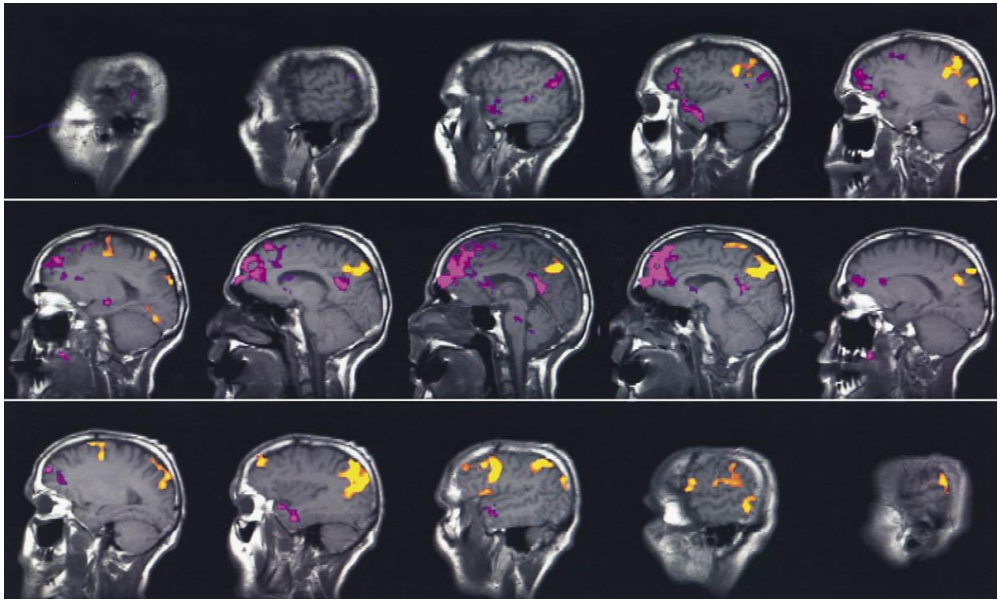
- Image of physiological activity of an organ
  - Example: Thyroid functional imaging depending on Iodine uptake



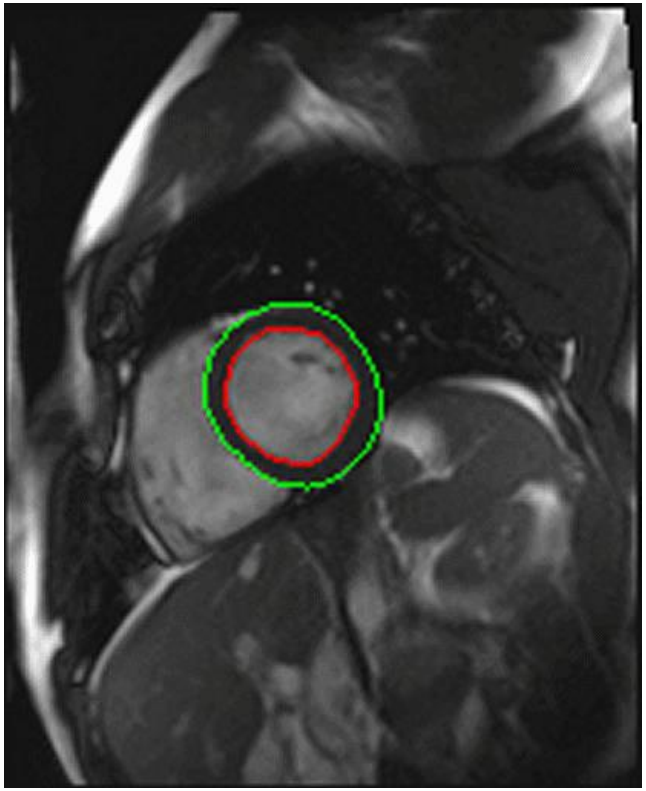


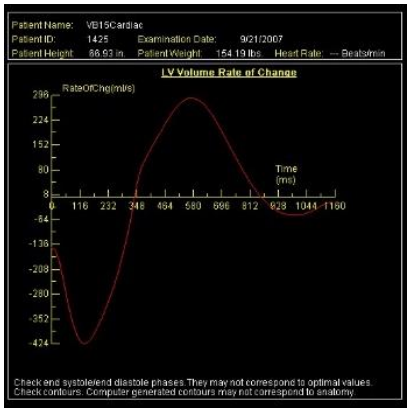
# Functional Imaging: Brain



# Functional Imaging: Heart

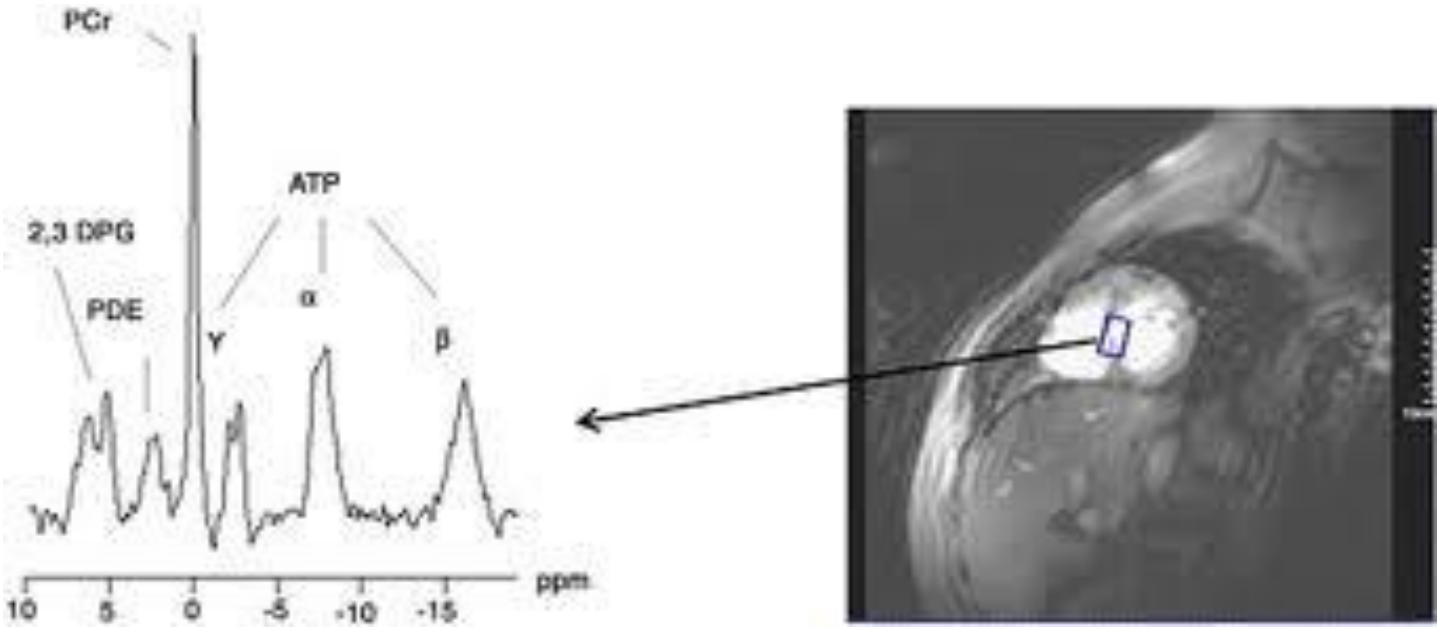




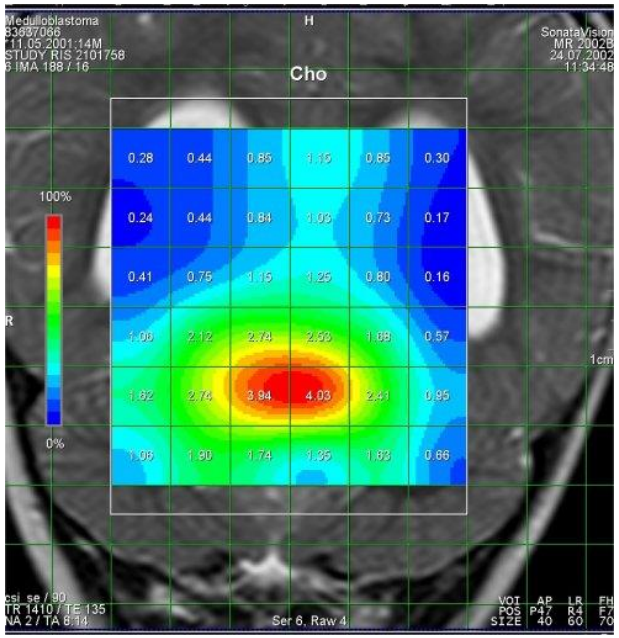


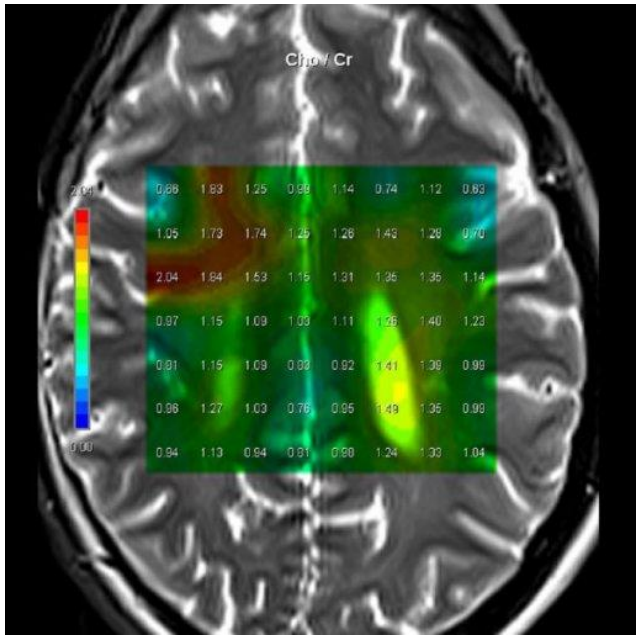
# Spectroscopic Imaging

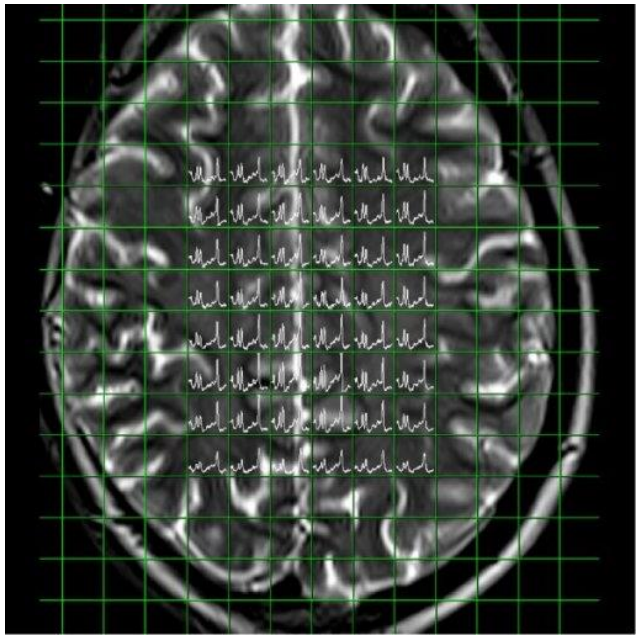
- Mapping of concentrations of certain chemical compounds inside the body



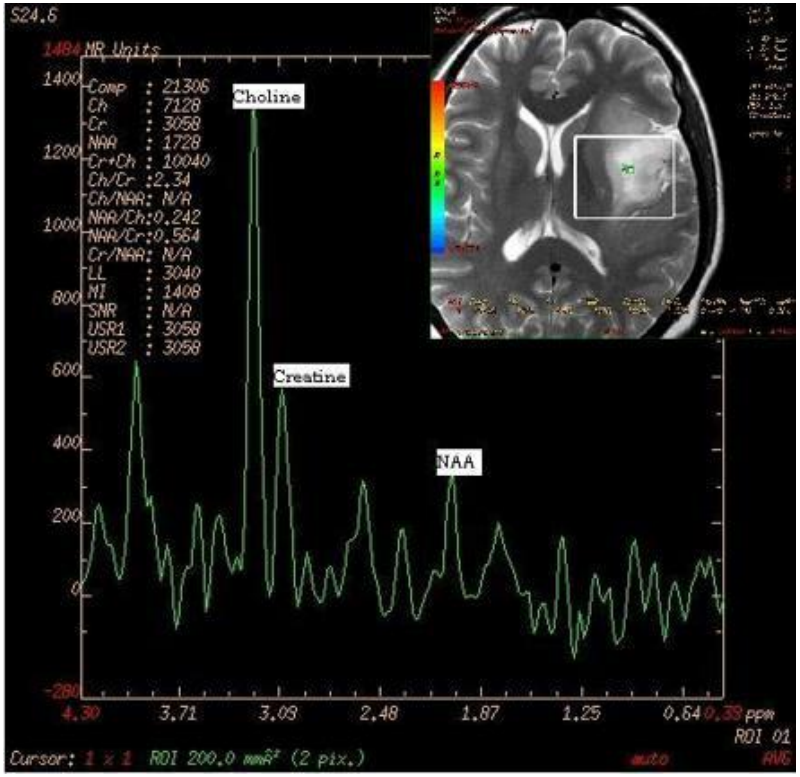
# Spectroscopic Imaging: Brain

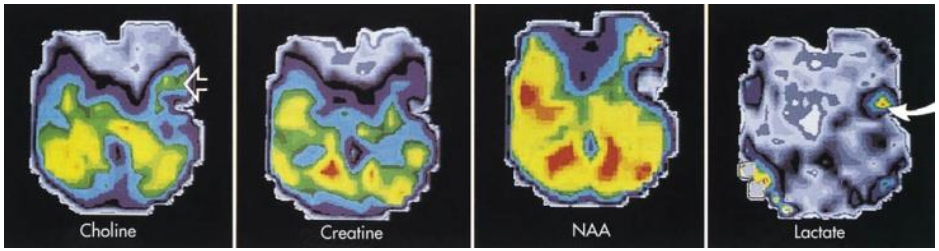


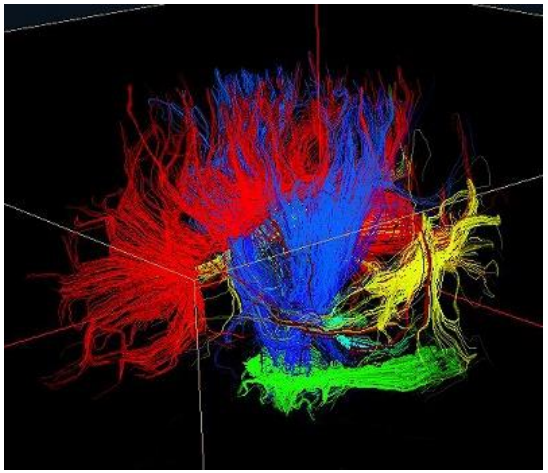
# Spectroscopic Imaging: Virtual Biopsy

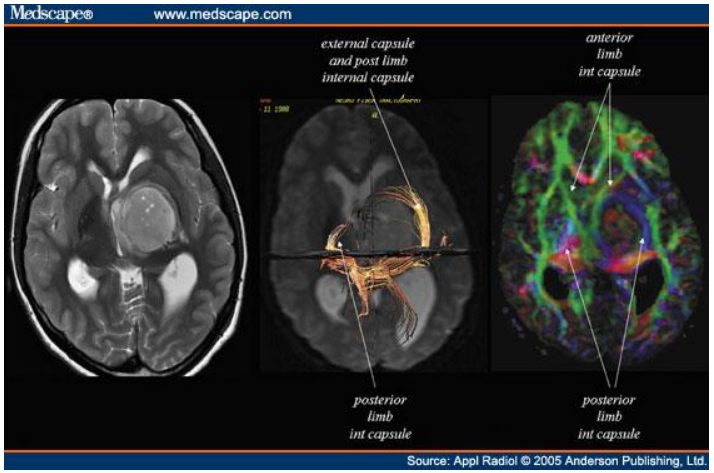


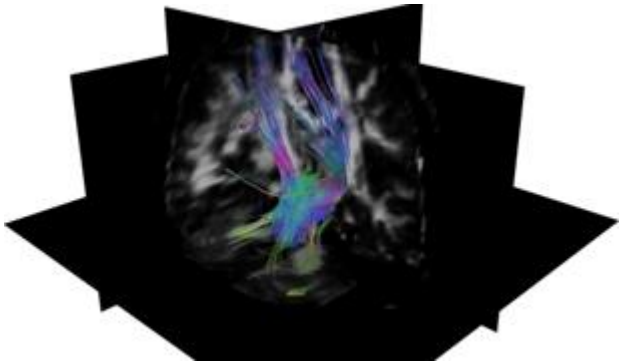



# Connectivity Imaging

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

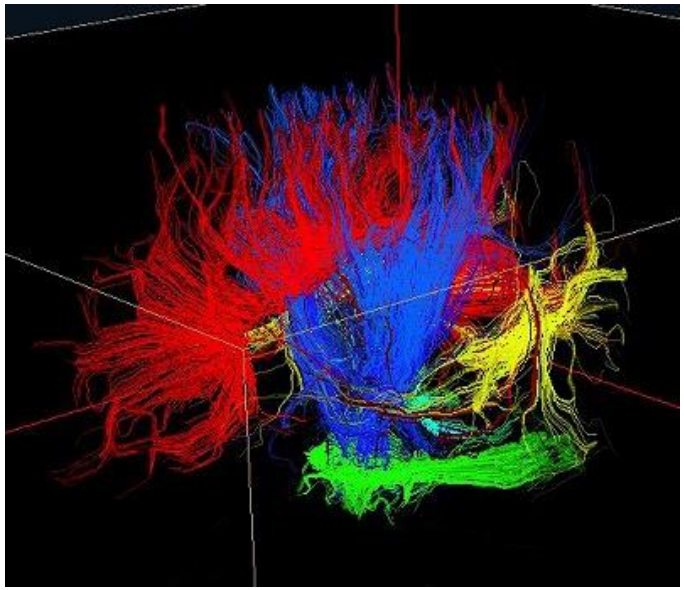


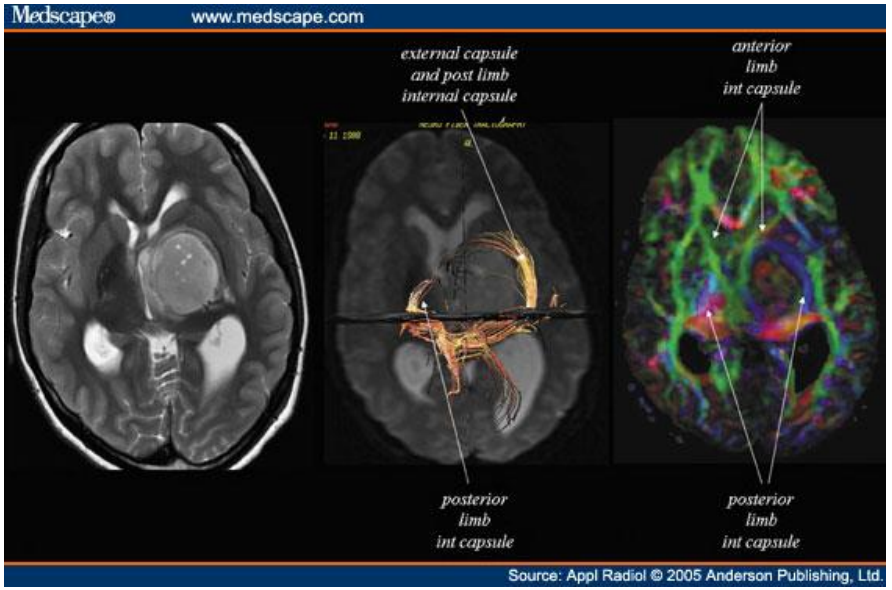


# Connectivity Imaging: Physical

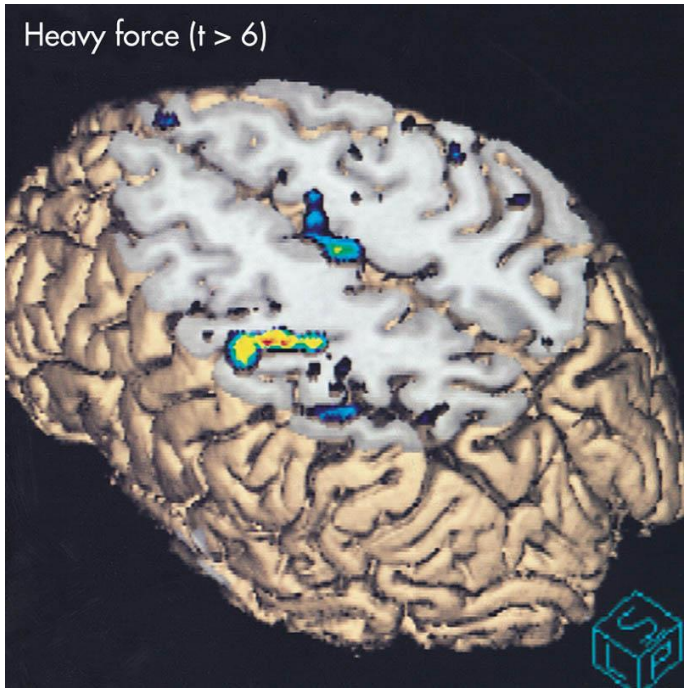
- Mapping of brain “wiring”

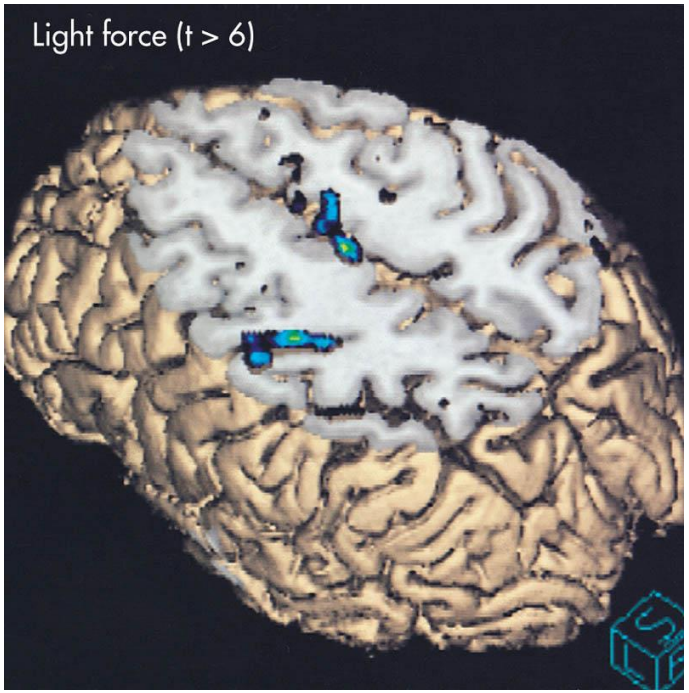




# Connectivity Imaging: Functional

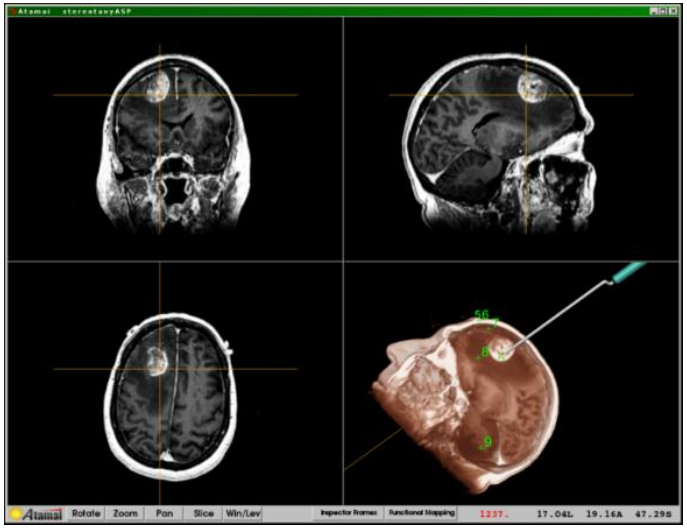
- Detection of brain areas that work together on certain functions

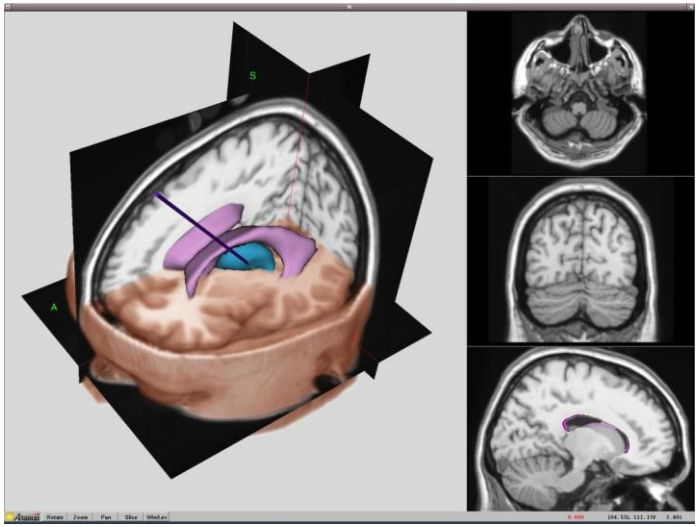


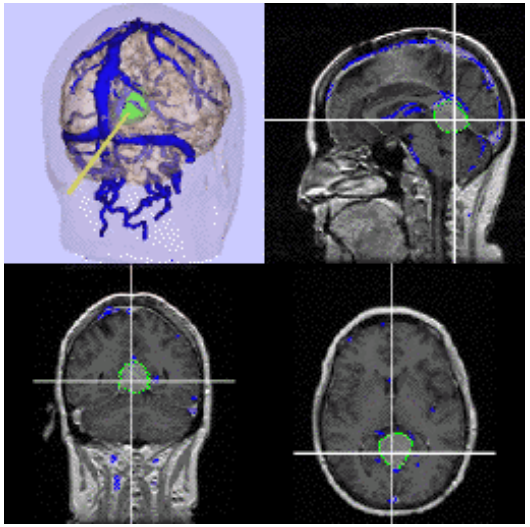



# Image Guided Surgery: Planning

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



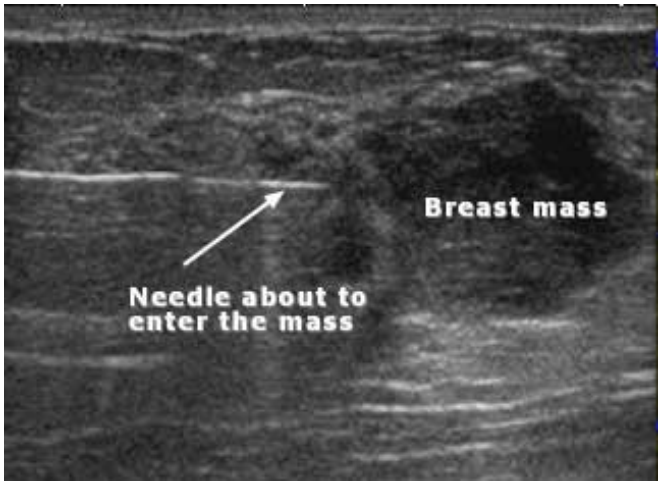


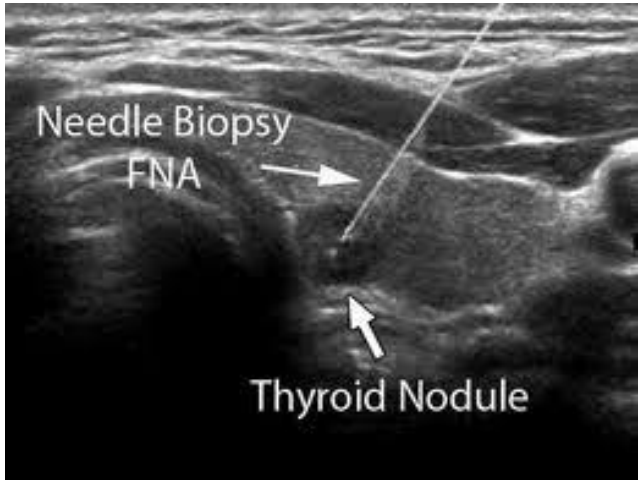
# Image Guided Surgery: Interventional

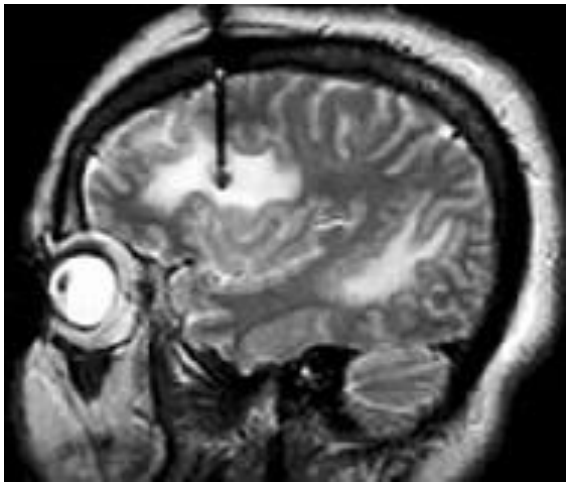
- Medical imaging systems designed for surgical interventions

# Image Guided Surgery: Biopsy

- Imaging of needle to accurately collect biopsy

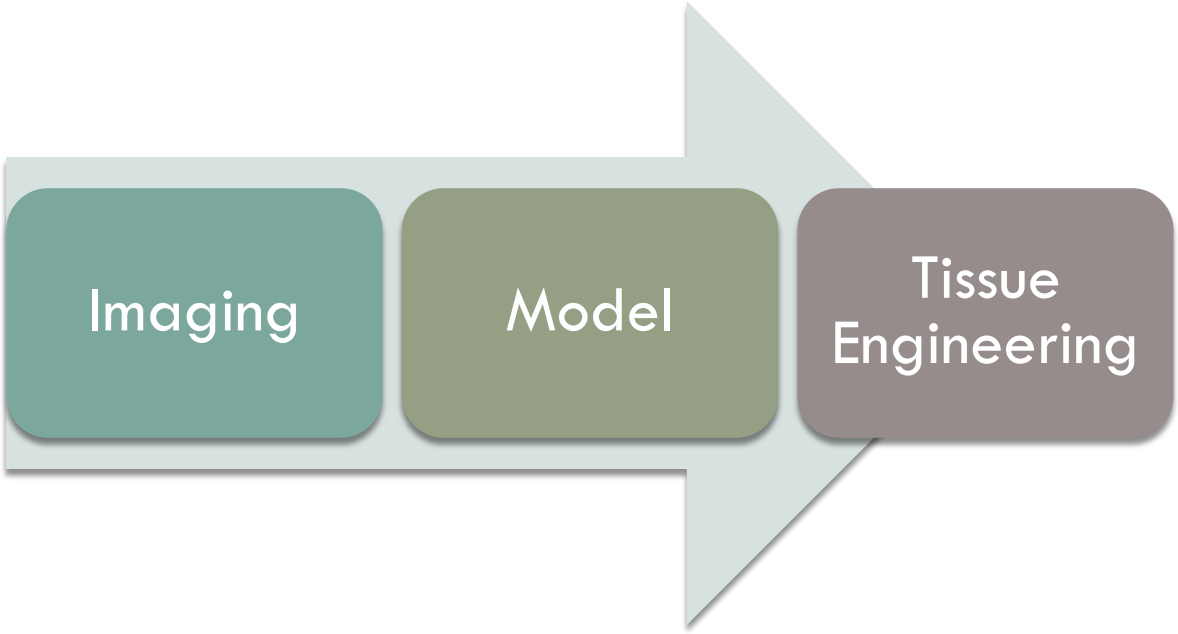


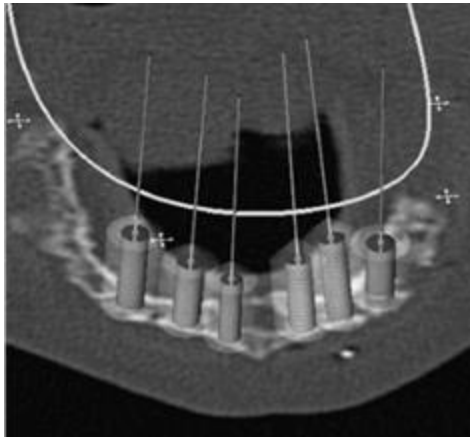



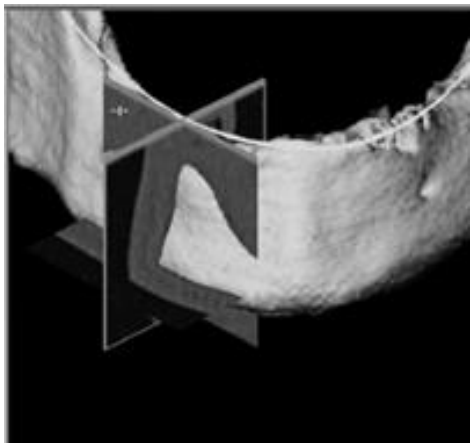



# Image Guided Tissue Engineering: Planning

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

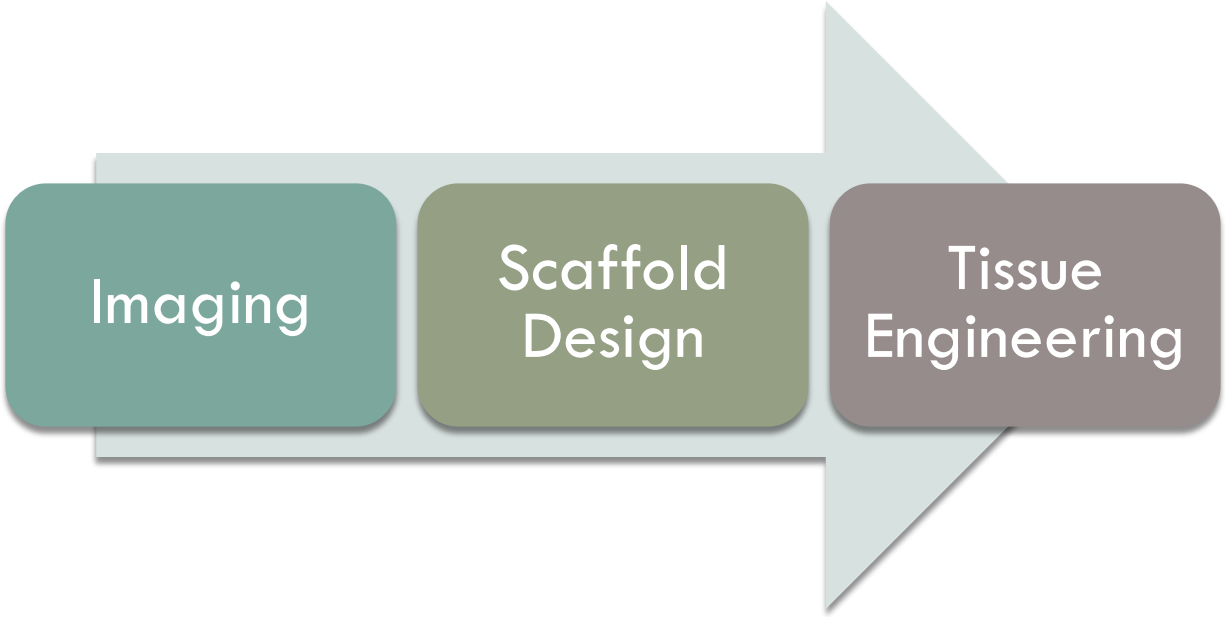


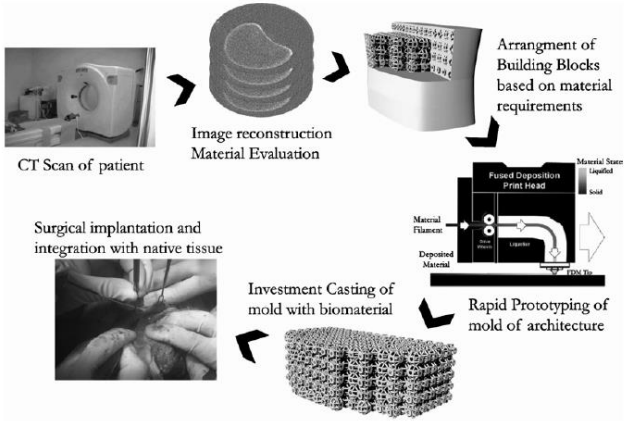





# Image Guided Tissue Engineering: Design

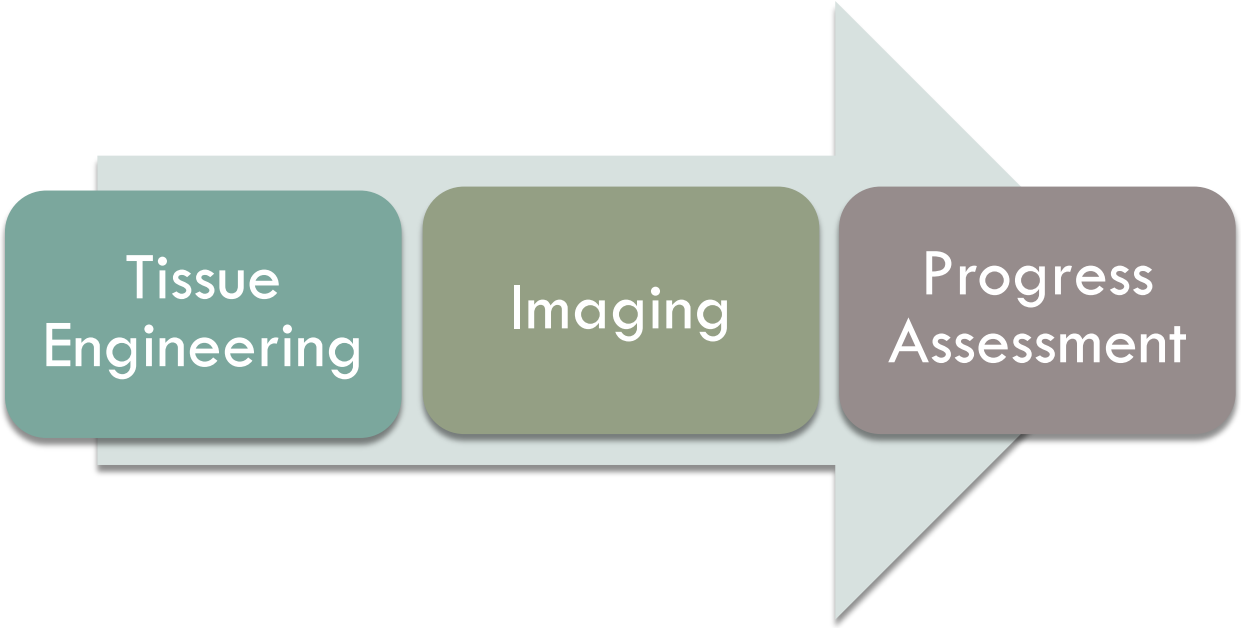
- Design of scaffold or implant using data from imaging
  - Accounts for complex patient-specific geometry
  - CAD/CAM methods

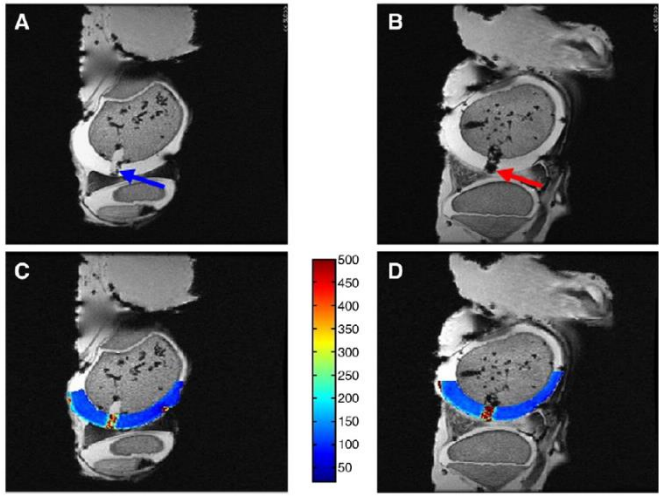


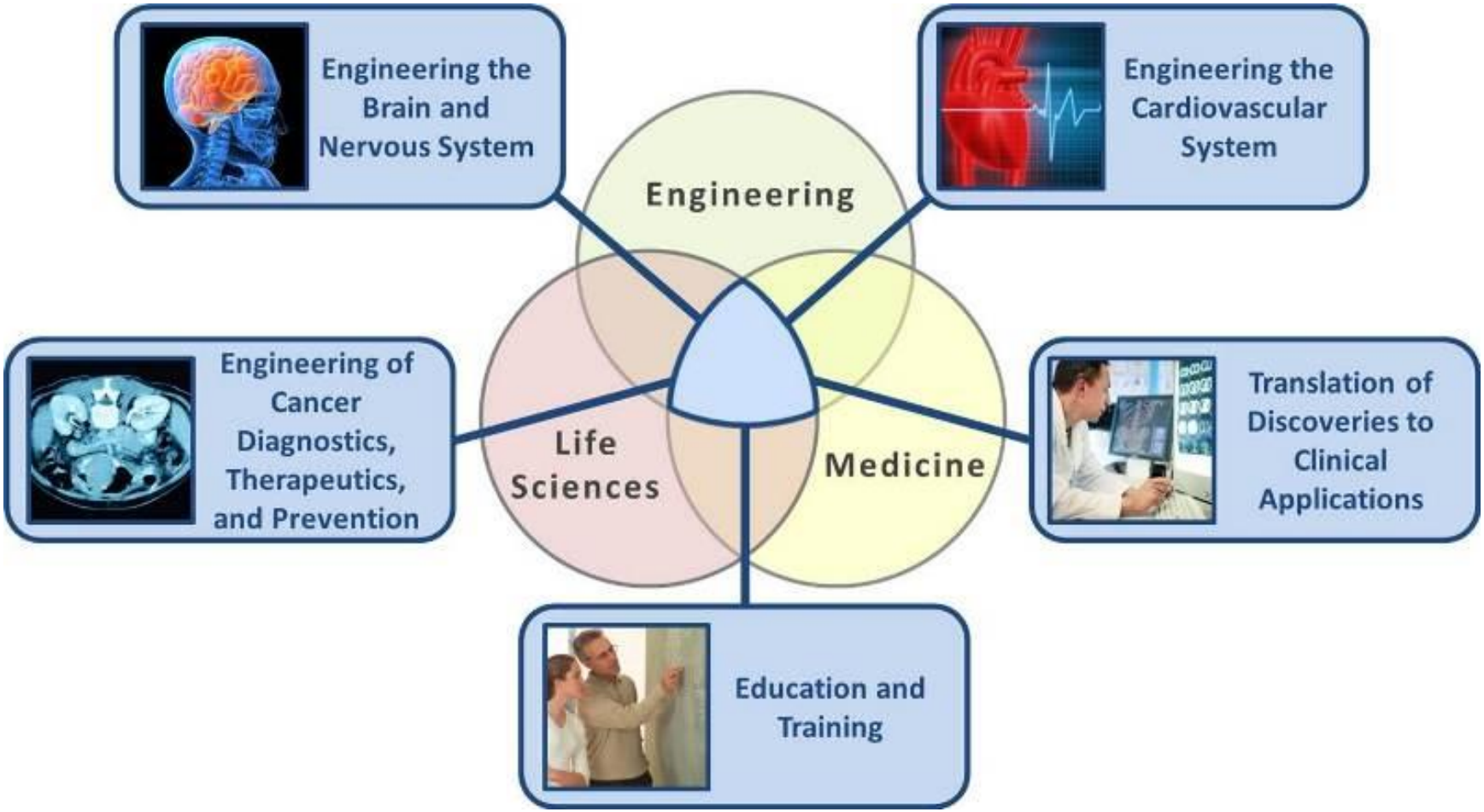
# Image Guided Tissue Engineering: Assessment

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



# 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