BIOMEDICAL ENGINEERING: HISTORICAL PERSPECTIVES AND PRESENT STATUS
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

- Engineering Firms
  - consulting firms
  - quality systems and control firms
- Molecular Biology Industry
  - genomics
  - sequence technology
- Manufacturing
- Pharmaceutical Industry
- Public Health
- Government
- Graduate Education
- Hospitals
- Rehabilitation
  - prosthetics
  - implants
  - fitting
  - customization
- Biomedical Engineering
- Medical devices
- Instrumentation
- Research and development
- Sales
- Pharma industry
- Cosmetics industry
- Public health organizations
- Environmental firms
- Non-profit organizations
- Federal agencies (e.g., NIH, FDA, NASA)
- State agencies
- Research hospitals
- Veterinary hospitals
- Animal labs
- Engineering, computer science
- Sciences
- Law school
- Medicine, dentistry
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
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
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: 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

- Image of a cardiac MRI with highlighted regions.
- Graph showing LV volume and time relationship.
- Table of left ventricular function parameters:
  - Ejection Fraction (EF): 65%
  - End Diastolic Volume (EDV): 161 mL
  - End Systolic Volume (ESV): 40 mL
  - Stroke Volume (SV): 121 mL
  - Cardiac Output (CO): 5.6 L/min
  - Cardiac Index (CI): 2.8 L/min
  - Average Heart Rate (HR): 50 bpm
  - Normalized to patient surface area: 1.8 m²
  - Patient height: 1.70 m
  - Patient weight: 70 kg

Note: Check ED & ES. Computer estimated ED & ES settings may not be accurate. Check contour. 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
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

- Engineering the Brain and Nervous System
- Engineering the Cardiovascular System
- Engineering of Cancer Diagnostics, Therapeutics, and Prevention
- Translation of Discoveries to Clinical Applications
- Education and Training
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