Biosignals and Systems

Lecture 1

Introduction

Introduction

- What is biomedical engineering?
  - Terminology, definitions
  - History of biomedical engineering
  - Sub-branches of BME

- A loose definition of Biomedical Engineering:
  - the application of engineering techniques and analyses to problem-solving in medicine and the biomedical sciences

Diversity in the terminology

- (bio)medical engineering,
- bioengineering, biotechnology
- clinical (medical) engineering
- medical technology.
- health care technology

Medical engineering (medical engineer)

- uses engineering concepts and technology for development of
  - instrumentation,
  - diagnostic and therapeutic devices,
  - artificial organs, and
  - other medical devices needed in health care and in hospitals
- role:
  - examine some portion of biology and medicine to identify areas in which advanced technology might be advantageous

Clinical engineering (clinical engineer)

- uses engineering, management concept, and technology
  - to improve health care in hospitals
    - better patient care at minimum costs thought the application of technology
- role is to provide services directly
  - related to patient care together with other health care professionals
  - problems originated from clinical environment

Clinical engineering

- responsible for
  - equipment effectiveness and
  - electrical safety in medical instrumentation
  - systems and power supply
- constrained by regulations
  - medical, federal, state, local, governmental, hospital

Bioengineering (bioengineer)

- basic research-oriented activity closely related to
  - biotechnology and
  - genetic engineering
    - modification of animal or plant cells to improve plants or animals to develop new micro-organisms
- Bioengineering integrates
  - physical,
  - chemical,
  - mathematical, and
  - computational sciences and
  - engineering principles

  to study biology, medicine, behavior, and health.

Bioengineering

- It advances fundamental concepts;
  - creates knowledge from the molecular to the organ systems levels;
  - develops innovative biologics, materials, processes, implants, devices, and informatics approaches

  for the
  - prevention,
  - diagnosis, and
  - treatment of disease,

  for patient rehabilitation, and for improving health

Biomedical Engineering (BME)

- a growing and expanding interdisciplinary profession
- concerned with the application of
  - engineering,
  - mathematics,
  - computing, and
  - science methodologies

  to the analysis of biological and physiological problems
- produce technological advances in health care

Biomedical Engineering (BME)

- Definition 1:
- "Biomedical engineering is a discipline that
  - advances knowledge in engineering, biology and medicine, and improves human health through cross-disciplinary activities that integrate the engineering sciences with the biomedical sciences and clinical practice."
- It includes:
  - The acquisition of new knowledge and understanding of living systems through the innovative and substantive application of experimental and analytical techniques based on the engineering sciences.
  - The development of new devices, algorithms, processes and systems that advance biology and medicine and improve medical practice and health care deliver

Biomedical Engineering (BME)

- Definition2:

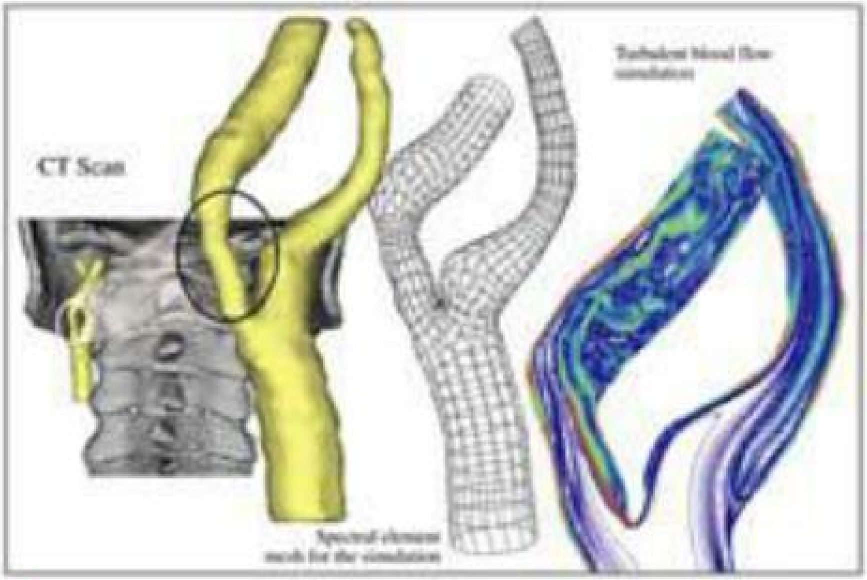
  The use of engineering technology, instrumentation and methods to solve medical problems, such as improving our understanding of physiology and the manufacture of artificial limbs and organs.

Biomedical engineers

- apply different engineering principles
  - electrical and electronics
    - instrumentation, bioamplifiers
  - mechanical,
    - artificial limbs, prostheses
  - physical
    - diagnostic imaging and therapeutic devices
  - chemical,
    - biosensors, chemical analysers
  - optical,
    - fiber optics, optical measurements
  - computer science
    - computational medicine, signal and image analysis, information systems
  - material science
    - implanted devices, artificial tissues

Biomedical Engineering (BME)

Biomedical engineers



- to understand, modify, or control biologic systems
- Application of
  - engineering system analysis
  - physiologic modeling,
  - simulation, and
  - control

Biomedical Engineering (BME)

Biomedical engineers

- design and manufacture products that can
  - monitor physiologic functions or
  - display anatomic detail
- Detection, measurement, and monitoring of physiologic signals
  - biosensors
  - biomedical instrumentation
  - Medical imaging
- assist in the diagnosis and treatment of patients
  - Computer analysis of patient-related data
  - clinical decision making
  - medical informatics
  - artificial intelligence
- supervise biomedical equipment maintenance technicians,
- investigate medical equipment failure,
- advise hospitals about purchasing and installing new equipment

Important milestones in the development of medical instruments…

- **Thermometer**
  - 1603, Galileo
  - 1625, body temperature measurement
- **Optical lens**
  - 1666, Newton
  - 1850-, ophthalmoscope, Helmholtz
- **Stethoscope**
  - 1819, hollow tube
  - 1851, binaural stethoscope
- **Hypodermic syringe**
  - 1853, Wood
- **X-ray**
  - 1895, Roentgen
  - 1896, in diagnosis and therapy
- **Radioactivity**
  - 1896, Curie
  - 1903, in therapy
- **Electrocardiograph**
  - 1887, Waller, capillary meter
  - 1903, Einthoven,
  - galvanometer 1928, vacuum tube
- **Electroencephalograph**
  - 1924, Berger
- **pH electrode**
  - 1906, Cremer
- **Electrical surgical unit, 1928**

…Important milestones in the development of medical instruments

- **Cyclotron, artificial radionuclides**
  - 1936, Lawrence
- **Assisting ventilator**
  - 1928, "iron lung"
  - 1945, positive pressure
- **Ultrasonic imaging**
  - pulse-echo, 1947
  - Doppler, 1950s
- **Magnetic Resonance Imaging (MRI)**
  - NRM, Bloch, Purcell, 1946
  - MRI, 1982
- **Computed tomography**
  - 1969, Cormack, Hounsfield
- **Electrical heart defibrillator**
  - 1956, Zoll
  - 1980, implanted
- **Implanted electrical heart pacemaker**
  - 1960, Greatbatch
- **Heart valves, 1975**
- **Cardiac catheter, 1975**
- **Artificial kidney (dialysis), 1960**
- **Artificial heart, 1984**

Some Branches of BME…

- **Biomechanics**
  - application of classical mechanics to biological or medical problems
  - study of movement of biologic solids, fluids and viscoelastic materials, muscle forces
  - design of artificial limbs
- **Biomaterials:**
  - study of both living tissue and artificial synthetic biomaterials (polymers, metals, ceramics, composites) used to replace part of a living system or to function in intimate contact with living tissue (implants)
  - biomaterials:
    - nontoxic,
    - non-carcinogenic
    - chemically inert
    - stable
    - mechanically strong

…Some Branches of BME…

- **Biomedical sensors**
  - physical measurements, biopotential electrodes, electrochemical sensors, optical sensors, bioanalytic sensors
- **Bioelectric phenomena:**
  - origin in nerve and muscle cells
  - generation in nerves, brain, heart, skeletal muscles
  - analysis,
  - modelling,
  - recording and
  - diagnosis

…Some Branches of BME…

- **Biomedical signal processing and analysis**
  - collection and analysis of data from patients
  - bioelectric, physical, chemical signals
  - online (embedded) and off-line processing and analysis
- **Medical imaging and image processing:**
  - provision of graphic display of anatomic detail and physiological functions of the body
  - medical imaging methods and devices
    - physical phenomena + detectors + electronic data processing+ graphic display = image
    - x-ray, gamma photons, MRI, Ultrasound

…Some Branches of BME…

- **Medical instruments and devices:**
  - design of medical instruments and devices to monitor and measure biological functions
  - application of electronics and measurement techniques to develop devices used in diagnosis and treatment of disease
    - biopotential amplifiers
    - patient monitors
    - electrosurgical devices
- **Biotechnology**
  - technology at cellular level

…Some Branches of BME…

- **Cell and tissue engineering:**
  - utilization of anatomy, biochemistry and mechanics of cellular and subcellular structures to understand disease processes and to be able to intervene at very specific sites.
  - design, construction, modification, growth and maintenance of living tissue (bioartificial tissue and alteration of cell growth and function)
- **Rehabilitation engineering:**
  - application of science and technology to improve the quality of life for individuals with physical and cognitive impairments (handicaps)

…Some Branches of BME…

- **Prostheses and artificial organs**
  - design and development of devices for replacement of damaged body parts
    - artificial heart,
    - circulatory assist devices,
    - cardiac valve prostheses,
    - artificial lung and blood-gas exchange devices,
    - artificial kidney, pancreas
- **Clinical engineering:**
  - medical engineering in hospitals, managementand assessment of medical technology, safety and management of medical equipment, product development

…Some Branches of BME

- **Physiologic modelling, simulation and control**
  - use of computer simulation to help understand physiological relationships and organ function, to predict the behavior of a system of interests (human body, particular organs or organ systems and medical devices)
  - developing of theoretical (computational, analytical, conceptual etc) models
- **Medical informatics:**
  - hospital information systems, computer-based patient records, computer networks in hospitals, artificial knowledge-based medical decision making
- **Bioinformatics**
  - The application of information technology to problem areas in healthcare systems, as well as genomics, proteomics, and mathematical modelling.

Medical devices

- Medical devices can be grouped according to the three areas of medicine:
- **Diagnosis**
  - diagnostic devices
- **Therapy**
  - therapeutic devices
  - application of energy
- **Rehabilitation**
  - Application of Assisting orthotic-prosthetic devices

Diagnostic devices

- Types of diagnostic devices
  - recording and monitoring devices
  - measurement and analysis devices
  - imaging devices
- importance of diagnostic devices
  - enhance and extend the five human senses to improve to collect data from the patient for diagnosis
  - the perception of the physician can be improved by diagnostic instrumentation in many ways:
    - amplify human senses
    - place the observer's senses in inaccessible environments
    - provide new senses

Therapeutic devices

- Objective of therapeutic devices:
  - deliver physical substances to the body to treat disease
- Physical substances:
  - Voltage, current
  - Pressure
  - Flow
  - Force
  - Ultrasound
  - Electromagnetic radiation
  - Heat
- Therapeutic device categories:
  - devices used to treat disorders
  - devices to assist or control the physiological functions

Assistive or rehabilitative devices

- Objective of rehabilitative devices
  - to assist individuals with a disability
- The disability can be connected to the troubles to
  - perform activities of daily living
  - limitations in mobility
  - communications disorders and
  - sensory disabilities
- Types of rehabilitative devices
  - Orthopedic devices
    - An orthopedic device is an appliance that aids an existing function
  - Prosthetic devices
    - A prosthesis provides a substitute

Some characteristics of BME

- methods and devices are used to solve medical problems
  - problems are difficult, diverse, and complex
  - solution alternatives are limited and specific to a certain problem
- Therefore we must know
  - what we are measuring or studying
  - what we are treating
  - which methodologies are available and applicable

Some characteristics of BME

- deals with biological tissues, organs and organ systems and their properties and functions
- bio-phenomena:
  - bioelectricity, biochemistry, biomechanics, biophysics
- requires their deep understanding and analysis
- Accessibility of data is limited,
- Interface between tissue and instrumentation is needed
- Procedures:
  - non-invasive
  - minimally invasive
  - invasive

Relationship of BME with other disciplines

– Relationship with Medicine

– Relationship with Physics

– Relationship with other fields of engineering

Relationship with Medicine

- Biomedical Engineering
  - application of engineering science and technology to problems arising in medicine and biology.
  - intersections between engineering disciplines
    - electrical, mechanical, chemical,…
    - with each discipline in medicine, such as
      - cardiology, pathology, neurology, …
    - biology
    - biochemistry, pharmacology,
    - molecular biology, cell biology, …

Physiological measurements

- important application of medical devices
  - physiological measurements and recordings
- important for biomedical engineer
  - to understand the technology used in these recordings but also
  - the basic principles and methods of the physiological recordings
- medical fields where physiological recordings play an important role
  - clinical physiology
  - clinical neurophysiology
  - cardiology
  - intensive care, surgery

important physiological parameters recorded

- parameters related to cardiovascular dynamics:
  - blood pressure
  - blood flow
  - blood volumes, cardiac output
- biopotentials:
  - electrocardiogram (ECG),
  - electroencephalogram (EEG),
  - electromyogram (EMG)
- respiratory parameters:
  - lung volumes and capacities,
  - air flow
- blood gases:
  - pressures of blood gases
  - oxygen saturation
  - pH and other ions

Relationship with Physics

- BME is closely related to physical sciences
- Medical Physics
  - applies physics in medicine
  - physical background of medical imaging methods used in radiology and nuclear medicine:
    - the production and safety issues of ionizing radiation,
    - interaction of the radiation with matter,
  - the physics of magnetic resonance phenomenon, ultrasonics, light etc.
  - physical background of radiotherapy
    - use of ionizing radiation to treat cancer

Relationship with Physics

- Biophysics
  - more related to (cell) biology
  - studies the processes in biology and medicine utilizing physics and engineering
- physical methods are applied
  - for molecules, cells, tissues, organs, body
  - to solve biologic problems,
  - biologic events are described using the concept of physics and analogues, and
  - the effects of physical factors on biologic processes is examined
- core concepts:
  - changes in state of the systems (P,V,T)
  - concentrations, osmolarities
  - Activities
  - internal energy, spontaneous processes
  - (electro)chemical equilibrium
  - enzyme reactions
  - diffusion
  - permeability
  - viscosity

Relationship with other fields of engineering

- BME applies principles and methods from engineering, science and technology
- closely related to many fields of engineering,
  - chemistry
  - computer science
  - electrical engineering
    - electronics, electromagnetic fields, signal and systems analysis
  - mathematics, statistics
  - measurement and control engineering
  - mechanical engineering
  - material science
  - physics etc.

Medical Terminology

- Importance of common language
  - essential for a meaningful communication,
    - especially between people representing different disciplines, like medicine and engineering.
- Physicians language is often regarded as obscure
- Medical terms are international, derived from the Greek and Latin!
- construction of the medical terms:
  - **root (word base)**
  - **prefixes**
  - **suffixes**
  - **linking or combining vowels**

Examples

- “Pericarditis“
  - prefix: peri- = “surrounding”
  - root: cardi = “heart”
  - suffix: -itis = “inflammation”
    - = an inflammation of the area surrounding the heart, or an inflammation of the outer layer of the heart, anatomically known as the pericardium
- “Phonocardiography“
  - phono = sound;
  - cardi = heart;
  - graph = write
    - = graphic recording of heart sounds

Some common prefixes

• **a(n)-**	without, not	*anemia, anesthesia*
• **anti-**	against	*antibiotic*
• **bi-,di-**	double,two	*bipolar, dipolar*
• **dys-**	bad, faulty	*dysfunction*
• **endo-**	within, inward	*endoscope, endocardium*
• **epi-**	outside	*epicardium*
• **extra-**	outside	*extrasystole*
• **hemi-**	half	*hemisphere*
• **hyper-**	abnormally high	*hypertrophy, hypertension*
• **hypo-**	abnormally low	*hypothermia, hypoxia*

Some common prefixes

• **inter-**	between	*intercellular, intercostal*
• **intra-**	within	*intracellular, intravascular*
• **para-**	beside, faulty	*paralysis*
• **patho-**	disease	*pathology*
• **per-**	through	*peroral, percutaneous*
• **peri-**	around	*pericardium, peritoneum*
• **poly-**	many	*polyarthritis*
• **retro-**	backward	*retrograde*
• **sub-**	under	*subcutaneous, subacute*

Some common suffixes

• **-esthesia**	feeling	*anesthesia*
• **-genesis**	origination	*neurogenetic*
• **-ia**	abnormal state	*claustrophobia*
• **-pathy**	disease	*myopathy*
• **-plegia**	paralysis	*hemiplegia*
• **-scope**	viewing	*microscope, endoscope*
• **-trophy**	development	*hypertrophy*

Terms for indicating location, direction

• Superior	-	inferior
• Distal	-	proximal
• medial	-	lateral
• anterior (ventral)	-	posterior (dorsal)
• superficial	-	deep
• afferent	-	efferent
• descending	-	ascending
• frontal	-	sagittal
• internal	-	external
• dexter	-	sinister

Examples of some medical and clinical abbreviations

- AP anteroposterior
- AV atrio-ventricular
- BP Blood pressure
- CO Cardiac output
- CT computed tomography
- ECG electrocardiogram
- EMG electromyogram
- ERG electroretinogram
- FVC forced vital capacity
- GI gastrointestinal
- GSR galvanic skin resistance
- HVL half value layer
- ICU intensive care unit
- I.V. intravenous
- LAO left anterior oblique
- LV left ventricular
- MRI magnetic resonance imaging
- NMR nuclear magnetic resonance
- PA posteroanterior
- RAO right anterior oblique
- RR Riva-Rocci, blood pressure
- SA Sinuatrial
- VF, VT ventricular fibrillation, tachycardia