BME 50
Introduction to Biomedical Engineering
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Introduction to Biomedical Engineering

Prof. Fiorenzo Omenetto
Science and Technology Building
Room 241
7-4972
fiorenzo.omenetto@tufts.edu

Class hours: MW 4:30 – 5:45 pm
Office hours: email

Class TA: Alexander Mitropoulos
alexander.mitropoulos@tufts.edu
OPTIONAL - course textbook

“Introduction to Biomedical Engineering”

Enderle, Blanchard, Bronzino, Prentice Hall

plus additional material given in class

Lectures will be posted on course website
Homework (when assigned) will be due every Monday in class.

We'll try to grade and return the homework by the following Monday.

Everyone will be allowed to turn in one assignment late (due the following class – Alex will keep track of this).

You can work with others on homework but write it up yourself.
We all have bad days and get things wrong.

Say what you’re doing and why you’re doing it!

(Always write and explain what you’re doing in your homework and exams).
<table>
<thead>
<tr>
<th>CLASS</th>
<th>DATE</th>
<th>TOPIC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Mon Jan 23</td>
<td>Introduction</td>
</tr>
<tr>
<td>2</td>
<td>Wed Jan 25</td>
<td>Course overview- introduction and perspective</td>
</tr>
<tr>
<td>3</td>
<td>Mon Jan 30</td>
<td>Modeling the human body – mechanical aspects</td>
</tr>
<tr>
<td>4</td>
<td>Wed Feb 1</td>
<td>Modeling the human body – electrical aspects</td>
</tr>
<tr>
<td>5</td>
<td>Mon Feb 6</td>
<td>Modeling the human body – more approaches</td>
</tr>
<tr>
<td>6</td>
<td>Wed Feb 8</td>
<td>Modeling the human body – more approaches</td>
</tr>
<tr>
<td></td>
<td>Mon Feb 13</td>
<td>Device Application – building an instrument</td>
</tr>
<tr>
<td>7</td>
<td>Wed Feb 15</td>
<td>1st Exam</td>
</tr>
<tr>
<td>8</td>
<td>Mon Feb 20</td>
<td>No classes - President’s day</td>
</tr>
<tr>
<td>9</td>
<td>Wed Feb 21</td>
<td>Biosensors</td>
</tr>
<tr>
<td>10</td>
<td>Thu Feb 23</td>
<td>Nanomedicine – reducing intervention scale</td>
</tr>
<tr>
<td>11</td>
<td>Mon Feb 27</td>
<td>Engineering at the cellular level. - Tissue Engineering</td>
</tr>
<tr>
<td>12</td>
<td>Wed Feb 29</td>
<td>Engineering at the cellular level. - Tissue Engineering</td>
</tr>
<tr>
<td>13</td>
<td>Mon Mar 5</td>
<td>Looking in - Optical Imaging, basics – body transparency</td>
</tr>
<tr>
<td>14</td>
<td>Wed Mar 7</td>
<td>Introduction to lasers, fiber optics and optical instruments</td>
</tr>
<tr>
<td>15</td>
<td>Mon Mar 12</td>
<td>Laser tools in medicine</td>
</tr>
<tr>
<td>16</td>
<td>Wed Mar 14</td>
<td>2nd Exam</td>
</tr>
<tr>
<td></td>
<td>Mar 17-25</td>
<td>SPRING RECESS</td>
</tr>
<tr>
<td>17</td>
<td>Mon Mar 26</td>
<td>Large data sets – the importance of data interpretation</td>
</tr>
<tr>
<td>18</td>
<td>Wed Mar 28</td>
<td>Too much information – statistics overview</td>
</tr>
<tr>
<td>19</td>
<td>Mon Apr 2</td>
<td>Ethics in the biomedical sciences</td>
</tr>
<tr>
<td>20</td>
<td>Wed Apr 4</td>
<td>Microscopy 1</td>
</tr>
<tr>
<td>21</td>
<td>Mon Apr 9</td>
<td>Microscopy 2</td>
</tr>
<tr>
<td>22</td>
<td>Wed Apr 11</td>
<td>Other medical imaging techniques – X-ray, MRI, ultrasound...</td>
</tr>
<tr>
<td></td>
<td>Mon Apr 16</td>
<td>No classes – Patriot’s day</td>
</tr>
<tr>
<td>23</td>
<td>Wed Apr 18</td>
<td>Biomaterials</td>
</tr>
<tr>
<td>24</td>
<td>Mon Apr 23</td>
<td>Application – silk optics</td>
</tr>
<tr>
<td>25</td>
<td>Wed Apr 25</td>
<td>Final review</td>
</tr>
<tr>
<td>26</td>
<td>Mon Apr 30</td>
<td>FINAL Exam</td>
</tr>
</tbody>
</table>
Goals:
- Exposure to the breadth and depth of the field
- Exposure to research opportunities at Tufts
- Get to know the Dept. faculty and graduate students
- Grasp of basic quantitative approach to biomedical problems

**Faculty**

**Core Faculty**

- **David Kaplan**, Ph.D., Syracuse University
  Department Chair and Professor
  Biopolymer Engineering, Biomaterials, Tissue Engineering, Bioengineering

- **Lauren Black**, Ph.D., Boston University
  Assistant Professor
  Cardiovascular tissue engineering, dynamic tissue mechanics and visualization, computational modeling, Myocardial Infarction, Tissue Engineering, Regenerative Medicine, Cardiogenesis

- **Mark Cronin-Golomb**, Ph.D., California Institute of Technology
  Professor
  Optical Instrumentation, Laser Tweezers, Atomic Force Microscopy, Nonlinear Optics, Biomedical Optics, Optical Tweezers, Atomic Force Microscopy

- **Sergio Fantini**, Ph.D., University of Florence
  Professor
  Biomedical Optics, Near-Infrared Spectroscopy, Diffuse Optical Imaging

- **Irene Georgakoudi**, Ph.D., University of Rochester
  Associate Professor
  Spectroscopic Imaging and Characterization, and in vivo Flow Cytometry

- **Catherine K. Kuo**, Ph.D., University of Michigan
  Assistant Professor
  Stem cells, Mesenchymal Stem Cells, Tissue Engineering, Regenerative Medicine, Biomaterials, Developmental Biology, Orthopaedics (Orthopedics)

- **Fiorello Omenetto**, Ph.D., University of Pavia
  Professor
  Ultrafast nonlinear optics, nanophotonics, biopolymer multifunctional materials, photonic crystals, photonic crystal fibers

- **Qiaobing Xu**, Ph.D., Harvard University
  Assistant Professor
  Biomaterials, drug delivery, micro/nanofabrication, tissue engineering
Brynne Cassidy
Sean Siebert

class of 2012 BSBME
DEFINITION – Biomedical Engineering

**Definition of ENGINEERING**

1. the activities or function of an *engineer*

2. a: the application of science and mathematics by which the properties of matter and the sources of energy in nature are made useful to people
   b: the design and manufacture of complex products
      <software engineering> — compare GENETIC ENGINEERING

3. calculated manipulation or direction (as of behavior) <social engineering> — compare GENETIC ENGINEERING

See engineering defined for English-language learners »
See engineering defined for kids »

**Examples of ENGINEERING**

· This control panel is a good example of smart engineering.

**First Known Use of ENGINEERING**

1720

**Definition of ENGINEER.**

1. a member of a military group devoted to engineering work

2. obsolete: a crafty schemer: PLOTTER

3. a: a designer or builder of engines
   b: a person who is trained in or follows as a profession a branch of engineering
   c: a person who carries through an enterprise by skillful or artful contrivance

4. a: a person who runs or supervises an engine or an apparatus
   See engineer defined for English-language learners »
   See engineer defined for kids »
DEFINITION – Biomedical Engineering

Application of engineering principles to understand, modify or control biological systems, as well as design and manufacture products that can monitor physiological functions and assist in the diagnosis and treatment of patients.

- Interdisciplinary branch of engineering that ranges from theoretical to experiment to applications
- Encompasses research, development, implementation and operation

Integration of Engineering & Biology & Medicine
the goal is to develop tools and methods that will ultimately lead to the well being of an individual.

How do we understand what is wrong and how to make things better?

we observe carefully, we model and interpret

How do we make things better?

by prevention
by fixing something broken
by eliminating something bad
by putting in something good
by (re)creating something good
Science & engineering of scale – smaller and smaller (e.g., implantable, invasive)

Man-machine interfaces (e.g., nerves, electronics)

In vivo diagnostics – non invasive (e.g., saliva)

In vitro systems to solve in vivo problems (e.g., tissue engineering)
What is biomedical engineering?

**bio**

...cells and cellular level phenomena, ...

**medical**

...the human body, health and well being

**engineering**

“the nuts and bolts”
literally...
the nuts and bolts
it is an incredibly interdisciplinary field
eliminate/cure something bad
surgical tools -
  remote surgery (robotics)
  new ways of cutting - laser tools
  new ways of targeting - nanotechnology

put in something good
(medicines/pharmaceuticals)
artificial limbs or joints
stents, valves, electronic controls
or artificial organs

(re)create something good
regenerative medicine –
tissue engineering
stem cells
artificial organs
# Universal Pain Assessment Tool

This pain assessment tool is intended to help patient care providers assess pain according to individual patient needs. Explain and use 0-10 Scale for patient self-assessment. Use the faces or behavioral observations to interpret expressed pain when patient cannot communicate his/her pain intensity.

### Verbal Descriptor Scale

<table>
<thead>
<tr>
<th>Scale</th>
<th>0 Pain</th>
<th>1 Mild Pain</th>
<th>2 Moderate Pain</th>
<th>3 Moderate Pain</th>
<th>4 Severe Pain</th>
<th>5 Worst Pain Possible</th>
</tr>
</thead>
<tbody>
<tr>
<td>WONG-BAKER FACS</td>
<td>Alert Smiling</td>
<td>No humor serious flat</td>
<td>Painful (speech or no verbal communication)</td>
<td>Wrinkled nose, frown, pursed lips</td>
<td>Slow blink, open mouth</td>
<td>Eyes closed, moaning, crying</td>
</tr>
<tr>
<td>GRIMACE SCALE</td>
<td>No Pain</td>
<td>Can be Ignored</td>
<td>Interferes with tasks</td>
<td>Interferes with concentration</td>
<td>Interferes with basic needs</td>
<td>Bedrest required</td>
</tr>
</tbody>
</table>

### Activity Tolerance Scale

<table>
<thead>
<tr>
<th>Scale</th>
<th>0 Pain</th>
<th>1 Mild Pain</th>
<th>2 Moderate Pain</th>
<th>3 Moderate Pain</th>
<th>4 Severe Pain</th>
<th>5 Worst Pain Possible</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPANISH</td>
<td>Nada de dolor</td>
<td>Unpquito de dolor</td>
<td>Un dolor leve</td>
<td>Dolor fuerte</td>
<td>Dolor demasiado fuerte</td>
<td>Un dolor insupportable</td>
</tr>
<tr>
<td>TAGALOG</td>
<td>Walang sakit</td>
<td>Konting sakit</td>
<td>Katatamang sakit</td>
<td>Matinding sakit</td>
<td>Pinaka-matinding sakit</td>
<td>Pinaka-matalang sakit</td>
</tr>
<tr>
<td>CHINESE</td>
<td>不痛</td>
<td>輕微</td>
<td>中度</td>
<td>嚴重</td>
<td>非常嚴重</td>
<td>最嚴重</td>
</tr>
<tr>
<td>KOREAN</td>
<td>통증 없음</td>
<td>약한 통증</td>
<td>보통 통증</td>
<td>심한 통증</td>
<td>아주 심한 통증</td>
<td>최악의 통증</td>
</tr>
<tr>
<td>PERSIAN (FARSI)</td>
<td>بدون درد</td>
<td>درد معتدل</td>
<td>درد شدید</td>
<td>درد بسیار شدید</td>
<td>درد بسیار شدید</td>
<td>درد بسیار شدید</td>
</tr>
<tr>
<td>VIETNAMESE</td>
<td>Không đau</td>
<td>Đau nhẹ</td>
<td>Đau vừa phải</td>
<td>Đau nặng</td>
<td>Đau thòi nặng</td>
<td>Đau ốm toàn cõng</td>
</tr>
<tr>
<td>JAPANESE</td>
<td>痛みがない</td>
<td>少し痛い</td>
<td>いくらか痛い</td>
<td>かなり痛い</td>
<td>ひどく痛い</td>
<td>ものすごく痛い</td>
</tr>
</tbody>
</table>
The Prize: Empowering Personal Healthcare

The Qualcomm Tricorder X PRIZE is a $10 million global competition to stimulate innovation and integration of precision diagnostic technologies, making reliable health diagnoses available directly to "health consumers" in their homes.

Advances in fields such as artificial intelligence, wireless sensing, imaging diagnostics, lab-on-a-chip, and molecular biology will enable better choices in when, where, and how individuals receive care, thus making healthcare more convenient, affordable, and accessible. The winner will be the team whose technology most accurately diagnoses a set of diseases independent of a healthcare professional or facility, and that provides the best consumer user experience with their device.
The findings of the Ancient Greek physician Galen, whose studies were based on the dissection of animals, were the only source of anatomical knowledge until 1543. Andreas Vesalius then published his classic work De humani corporis fabrica which was based on his own observation of human corpses.
We observe carefully, we model and interpret
Tulp had decided to be shown in his natural environment, giving an anatomy lesson. Most of the seven other figures in the painting were wealthy middle-class citizens of Amsterdam. Only two of the observers were physicians.
We observe carefully, we model and interpret
Tools to observe
Tools to observe

The New England Journal of Medicine selected medical imaging as one of the 11 most important innovations of the past 1,000 years. Dramatic advances in medical imaging technologies have allowed physicians to detect, diagnose, and treat diseases earlier and more accurately, often reducing costs. Medical imaging is extending human vision into the very nature of disease, enabling a new and more powerful generation of diagnosis and intervention.
Larmor Frequency (interdisciplinarity)-Transforming an equation into an instrument

When a magnetic moment is placed in a magnetic field it will tend to align with the field. Classically, a magnetic moment can be visualized as a current loop and the influence toward alignment can be described as the torque on the current loop exerted by the magnetic field. The idea of the magnetic moment as a current loop can be extended to describe the magnetic moments of orbital electrons, electron spins and nuclear spins. In each case the magnetic moment is associated with the angular momentum, and a torque can be identified which tends to align the magnetic moment with the magnetic field. In the nuclear case, the angular momentum involved is the intrinsic angular momentum $I$ associated with the nuclear spin.

When you have a magnetic moment directed at some finite angle with respect to the magnetic field direction, the field will exert a torque on the magnetic moment. This causes it to precess about the magnetic field direction. This is analogous to the precession of a spinning top around the gravity field. The torque can be expressed as the rate of change of the nuclear spin angular momentum $I$ and equated to the expression for the magnetic torque on the magnetic moment

$$\tau = \frac{\Delta I}{\Delta t} = I \sin \theta \Delta \phi = |\mu B \sin \theta| = \frac{ge}{2m_p} IB \sin \theta$$

which when put in derivative form gives a precession angular velocity

$$\omega_{\text{Larmor}} = \frac{d\phi}{dt} = \frac{ge}{2m_p} B$$

It can also be visualized quantum mechanically in terms of the quantum energy of transition between the two possible spin states for spin 1/2. This can be expressed as a photon energy according to the Planck relationship. The magnetic potential energy difference is $h\nu = 2\mu B$. The angular frequency associated with a "spin flip", a resonant absorption or emission involving the spin quantum states is often written in the general form

$$\omega = \gamma B$$

where $\gamma$ is called the gyromagnetic ratio (sometimes the magnetogyric ratio). Note that this frequency is a factor of two higher than the one above because of the spin flip with energy change $\Delta E = 2\mu B$.

This nuclear spin transition for nuclei placed in a magnetic field is the basis for nuclear magnetic resonance (NMR).
Transforming an equation into an instrument

$$\omega_{Larmor} = \frac{d\phi}{dt} = \frac{ge}{2m_p} B$$

**CREATING REFINED ANATOMICAL IMAGES**

Within the metallic cocoon of an MRI scanner, the patient is surrounded by four electromagnetic coils and the components of a transciever:

- **Scanner**
  - Uses electromagnets and radio signals to produce cross-sectional images.

- **Y Coil**
  - Creates varying magnetic field from top to bottom across scanning tube.

- **Z Coil**
  - Creates varying magnetic field from head to toe within scanning tube.

- **Transciever**
  - Sends radio signals to protons and receives signals from them.

- **X Coil**
  - Creates varying magnetic field from left to right across scanning tube.

- **Main Coil**
  - Surrounds patient with uniform magnetic field.

- **Patient**
  - Wears loose clothing; must empty pockets of metallic objects that could prove harmful if moved by magnetic force.

*Philips medical*
Larmor Frequency and sports
Functional near-infrared imaging of the brain

Right hand exercise  Left hand exercise

Δ [Hb]

Fantini, 2004
We observe carefully, we model and interpret.

Fig. 1.20. Heart modeling for surgical planning and prosthesis design (Costa 94a,b)
We observe carefully, we model and interpret.

Fig. 4.6. Finite element model of finger (Gourret 89)

Fig. 2.25. Coordinate systems definition for the human upper limb joints (Maurel 96)
The approach was applied to the forearm flexion movement of a reduced model of the upper limb including three action lines: the long head of the biceps brachii, the brachialis and the brachioradialis. The flexion was performed in the range of 45° to 135° in a time period of 1 s with an additional mass of 10 kg in hand.

We observe carefully, we model and interpret

THOR – the 50th percentile male dummy - (head)

THOR is packed with sensors

THOR – the 50th percentile male dummy - (head)

Load sensing face with regional measurement capability

Multi-directional head/neck design with a) kinematic performance matched to human volunteer frontal, lateral, and rear impact data, and b) distinct cervical column and "muscular" load paths

Human-like thoracic structure with clavicle representation, multiple high-speed 3D deflection instruments at four locations on the anterior ribcage, and optional mid-sternum uni-directional displacement measurement

Improved shoulder design with more human-like mobility

Restorable abdomen design featuring an upper module with compression measurement and a lower module with continuous bilateral 3D deflection measurements

Pelvis design with revised anthropometry and flesh configuration, injury assessment capability at the hips, and submarining detection features

THOR – the 50th percentile male dummy

Compliant femur design to assist in generation of more realistic femur loads

Lower extremity design (Thor-Lx) with more human-like ankle/foot motions, a representation of the Achilles tendon load path, and substantially advanced injury assessment capabilities

http://www.nhtsa.gov/Research/Biomechanics+%3ETrauma/THOR+Advanced+Crash+Test+Dummy
Bio RID II, SID-IIS and THOR. The dummies come in all sizes and shapes to simulate the impact on drivers and passengers from 6-month-old babies to pregnant women. (She comes with a mock uterus with built-in sensors.) Even though the dummies don’t particularly look impressive, with plastic limbs and wires hanging loose, they cost more than Toyota’s highest-end car model, averaging around 12 million yen ($150,000 U.S. dollars). The dearest of them, called “Hybrid III AM50 High-Meka Dummy” has a price to match its hefty name: 200 million yen ($2.5 million), an official explained. It’s all part of Toyota’s aim to reduce road-related deaths and serious injuries. Back in the 80s, they used to use live pigs for safety tests, strapping the swines into cars with seatbelts, the official said, sotto voce. Today’s pigs have stricter animal rights laws – and the crash-test dummies – to thank.

We observe carefully, we model and interpret to try to replicate

(1) Human hand

(a) Human hand

(b) Computer tomography or magnetic resonance imaging

(b) Computer tomography or magnetic resonance imaging

(c) Processed image

(c) Processed image

(d) Finite-element mesh

(d) Finite-element mesh

Starting with (a) an individual human hand, we obtain (b) raw magnetic resonance imaging or computed tomography scans. The scan shown here is a cross section of bones and surrounding tissues proximal to the knuckles. From many cross sections, we (c) process the images and then generate (d) a high-quality, three-dimensional mesh that is suitable for finite-element analysis.
We observe carefully, we model and interpret to try to replicate
SPECIAL REPORT
PROSTHETIC ARMS

IEEE SPECTRUM editors examine the new generation of high-tech prosthetic arms from fingertip to arm socket, revealing the workings of the most advanced human-machine interfaces engineers have ever developed.

Dean Kamen's "Luke Arm" Prosthesis Readies for Clinical Trials
1 February 2008

Reengineering the Prosthetic-Arm Socket
1 February 2008

Fueling a Robotic Arms Race
1 December 2007

Artificial Arm Researchers Restore Feeling of Missing Limb
1 December 2007

Mastering the Brain-Computer Interface
15 April 2008

Sensitive Synthetic Skin in the Works for Prosthetic Arms
1 January 2008

Engineers Work on Laser-Based Brain-Machine Interface for Prosthetic Arm
15 February 2008
Surgery (eliminate/cure)
New ways to cure

vs.

[Images of medical equipment]
Interchangeable instruments with EndoWrist™ technology simultaneously follow surgeon’s hand and wrist movements.

Anesthesiologist

Assistant monitor

Surgical cart

Assistant

Surgeon at operative console

Nurse

Surgeon uses open-surgery hand movements which are precisely replicated in the operative field by the instruments.
New ways to cure
Angioplasty techniques. Computer illustration of balloon and laser angioplasty. Angioplasty is a surgical procedure to unblock and widen arteries that are narrowed or obstructed due to the formation of fatty plaques (atheroma), clots or scar tissue. A catheter (tube) is inserted into the artery. In the established technique (top), a balloon (beige) is inflated inside the affected area. The newer method (bottom) uses pulses of laser light (transmitted through a fibre optic) to destroy the blockage ahead of the catheter. This may be less traumatic to the arterial wall, decreasing the chance of narrowing recurring.
New ways to cure - lasers
New ways to cure – gene therapy

We observe carefully, we model and interpret.

Taken from Nature Jan, 2002
Paper by L van’t Veer et al
Gene expression profiling predicts clinical outcome of breast cancer.
Tissue Engineering - Strategy
Tissue Engineering - Strategy

- Cells
- Scaffold
- Bioreactor
- Cartilage
- Bone
- Ligament
- Myocardium

Vunjak, 2004
Worms and rugby
Worms and rugby

Serica Technologies' silk fibroin-based SeriACL™ graft (top) is intended to replace tissue harvested from the patient to repair the anterior cruciate ligament (ACL) of the knee, providing a base (bottom) to be infiltrated with native cells and remodeled into functional tissue.
Nature vs. the engineer
Stents

- Stents - implanted to provide mechanical support while artery repairs, fights the effects of elastic recoil and negative remodeling
- Stent industry is a two billion dollar industry and growing
- 800,000/yr in US

Metallic stents

We observe carefully, we model and interpret to try to replicate
We observe carefully, we model and interpret to try to replicate Intervertebral Disc

- Surgery
- Biomaterial
- Tissue Engineering
- Gene Therapy
Implanted Pump
- Approved in France, currently in trial in US
- Surgically placed into lower left quadrant of the abdomen.
- Catheter delivers insulin directly to the peritoneal cavity

Insulin Delivery

We observe carefully, we model and interpret to try to replicate
Electronic Pacemakers

- Effective, reliable
- Limited rate control, battery replacement
Product Development

Problem – Research - Design – Product – Implantation -

Redesign
Lasers for imaging – confocal microscopy

- Images of thick specimens at various depths
- Rejects out-of-focus information

Rat bone marrow stromal cells grown on tissue culture plastic (2D), 3 days after seeding. Actin staining *(rhodamine phalloidin)* - Bar = 30 µm

Human bone marrow stromal cells grown on silk fibroin fiber matrix (3D), 3 days after seeding. Live-dead staining. Bar = 40 µm

**Calcein AM**: stains live cells into green

**Ethidium homodimer-1**: stains dead cells into red
Quantum Dots for Imaging

- Long-term imaging, Cell-line tracking
- Specific labeling of tissue/cell structures
- Multiple detection

- Endothelial cells in lung blood vessels
  - Green QDs: Lymph vessel
  - Red QDs: Blood vessel

Core: CdSe
Shell: ZnS
Core: 3 to 10 nm
Shell: + 1 nm

- Cancer

Greiner, 2004
Some Disciplines of Biomedical Engineering

- **Biomechanics** – study of static and fluid mechanics associated with physiological systems
- **Biomaterials** – design and development of bioimplantable materials
- **Biosensors** – detection of biological event and their conversion to electrical signals
- **Physiological Modeling, Simulation and Control** – use of computer simulation to develop an understanding of physiological relationships
- **Biomedical Instrumentation** – to monitor and measure physiological events
- **Medical and Biological Analysis** – to detect, classify and analyze bioelectric signals
- **Rehabilitation Engineering** – design and development of therapeutic and rehabilitation devices and procedures
- **Prosthetic Devices and Artificial Organs** – design and development of devices for replacement or augmentation of bodily function
- **Medical Informatics** – of patient-related data, interpret results and assist in clinical decision making, including expert systems and neural networks
- **Medical Imaging** – to provide graphic displays of anatomical detail and physiological function
- **Biotechnology** – to create or modify biological materials for benefit, including tissue engineering
- **Clinical Engineering** – design and development of clinically related facilities, devices, systems and procedures
- **Biological Effects or Electromagnetic Fields** – study of the effects of electromagnetic fields on biological tissue
Biomedical Engineers – Examples of Some Activities

- Application of engineering system analysis (physiologic modeling, simulation and control) to biological problems
- Detection, measurement, and monitoring of physiologic signals (biosensors, biomedical instrumentation)
- Diagnostic interpretation via signal-processing techniques of bioelectric data
- Therapeutic and rehabilitation procedures and devices (rehabilitation engineering)
- Devices for replacement or augmentation of bodily functions (Artificial organs)
- Computer analysis of patient-related data and clinical decision making (medical information and artificial intelligence)
- Medical imaging (graphic display of anatomic detail or physiological function)
- Creating of new biological products (biotechnology and tissue engineering)