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Biomedical Engineering +
Leonard Gelfand Center

Biomedical Engineering Focus Areas: An Introduction

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This educational resource for middle and high school audiences was developed as a project by Carnegie Mellon student, Olivia Olshevski, for the course *Directed Study*, taught by Dr. Conrad Zapanta and co-advised by Dr. Judith Hallinen during the fall of 2021.

NOTE: Sources for content and for images that are included in these slides can be found in the accompanying Slide Guide and on the slides at the end of this file.

CAUTION: If you are attempting an experiment, it is important to make sure that you are following all safety steps. All experiments should be completed with supervision of a adult. Weather permitting, we recommend taking messy experiments outside. Remember to wear safety gear like gloves, aprons, and goggles, especially for experiments with chemical reactions!

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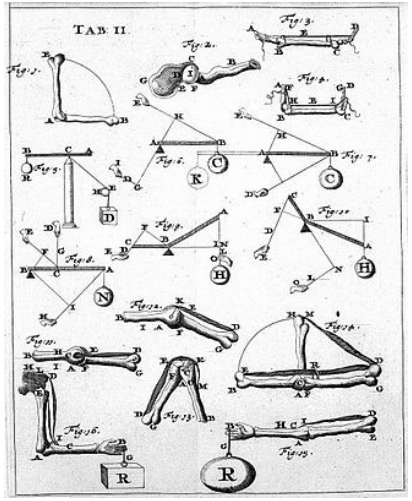
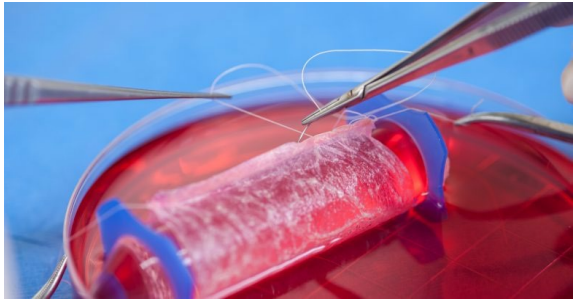
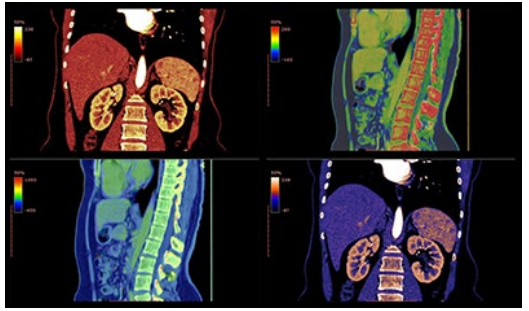
Be SAFE and enjoy the module!

What do biomedical engineers do?
BME Focus Areas

- Biomechanics
- Biomaterials and Tissue Engineering
- Biomedical Devices
- Bioimaging and Signal Processing
- Cellular and Molecular Biotechnology
- Neuroengineering







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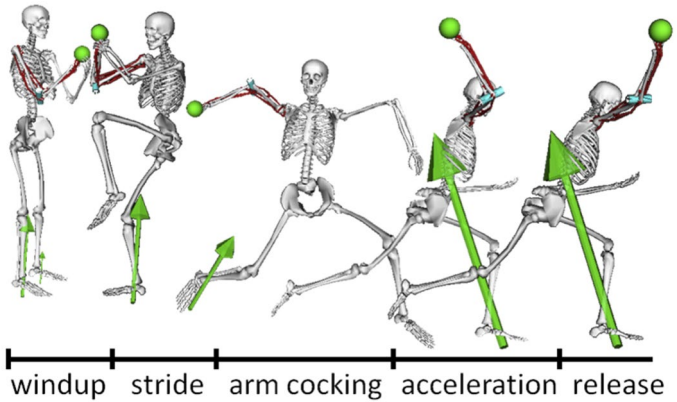
Biomechanics

Definition & Scope: Biomechanics

The scientific study of the mechanics of living structures (or of structures produced by organisms) -*Nature* definition

- What you study
  - Mechanical properties of tissues (macro and micro)
    - Micromechanics
    - Solid mechanics
    - Viscoelasticity
    - Fluid mechanics
    - Entropic force, diffusive force, osmotic force



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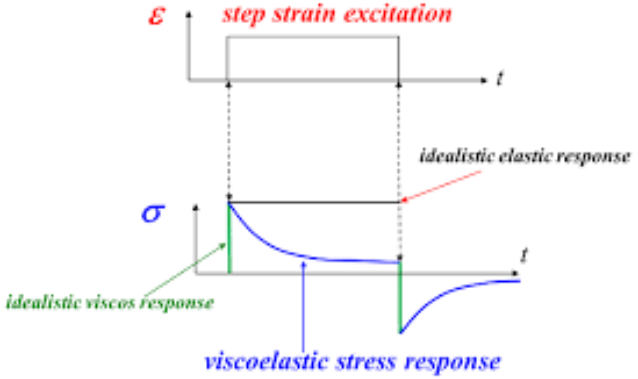
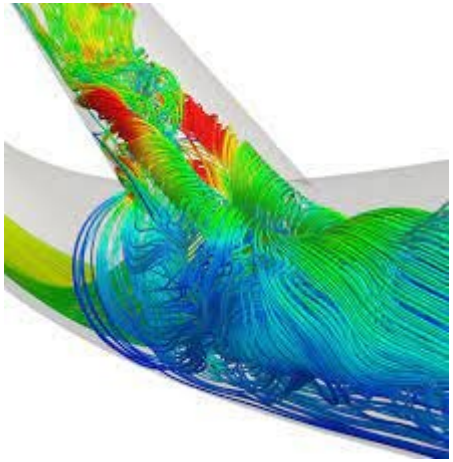
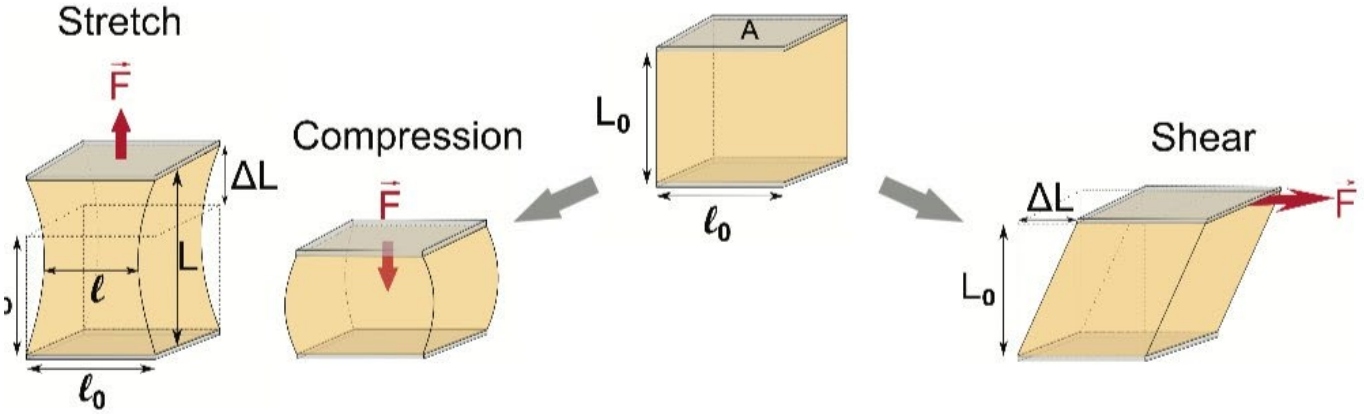
Applications: Biomechanics

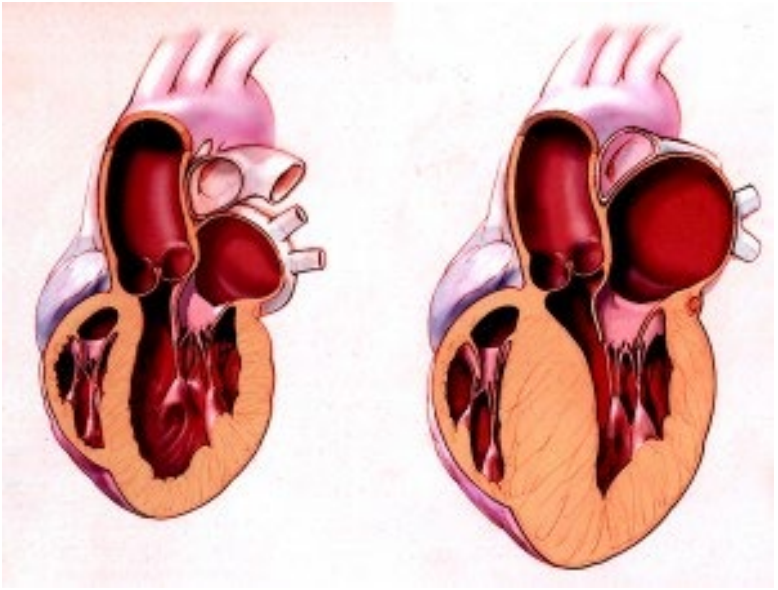
- Cardiovascular fluid mechanics and dynamics
- Cell mechanics
- Solid mechanics of biological materials
- Biological viscoelastic solids and fluids







Example 1: Cardiovascular Mechanics



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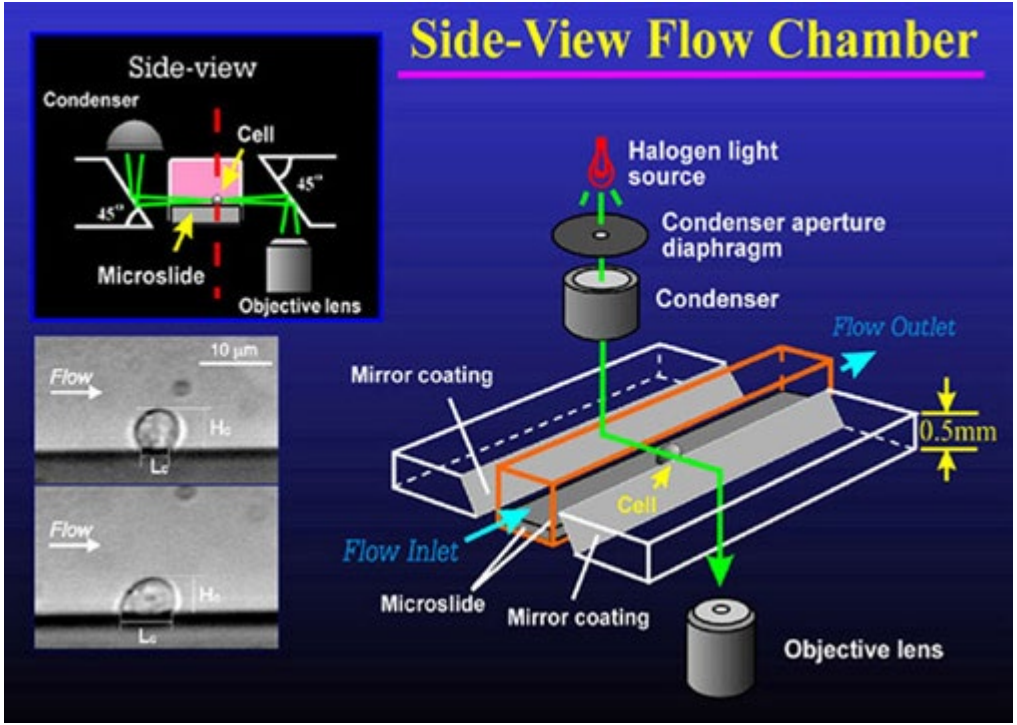
Example 2: Cellular Biomechanics



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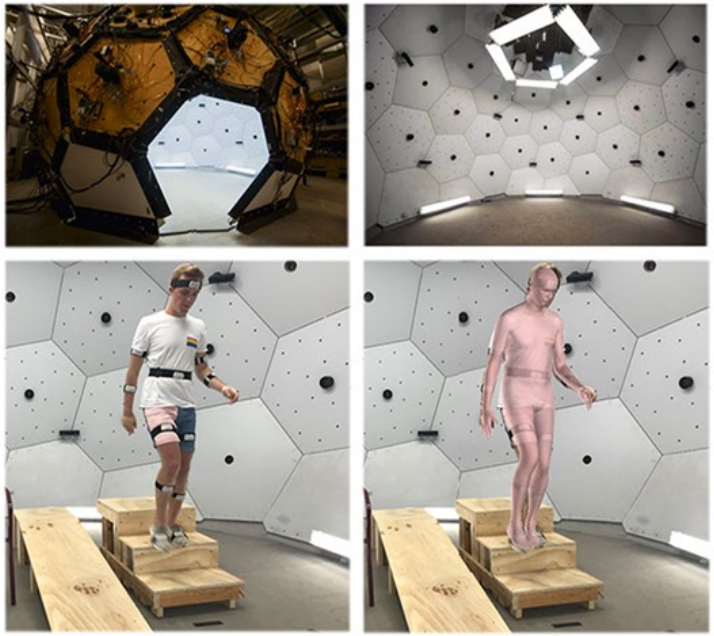
CMU Connection: Natural Environment Biomechanics (Musculoskeletal Biomechanics Lab)



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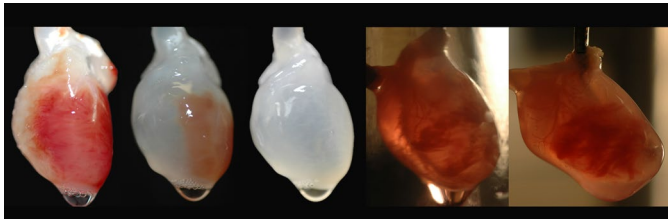
Biomaterials and Tissue Engineering

Definition & Scope: Biomaterials and Tissue Engineering

The field of study in which man-made materials are developed for medical treatments (biomaterials) and living functional tissue is produced (tissue engineering)

- What you study
  - Interactions between materials and cells or tissues (and their effects)
  - Major body responses (wound healing, immune response, foreign body response)
  - Characterizing biomaterials (metals, ceramics, polymers)
  - Natural and synthetic materials
  - Cell culture
  - Material biocompatibility



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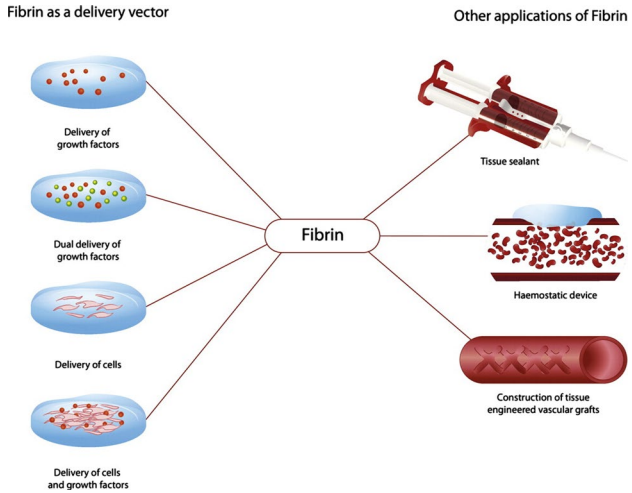
Applications: Biomaterials and Tissue Engineering

- Artificial organs
- Wound healing
- Bioscaffolds
- Collagen biomaterials
- Implant failure and material reactions



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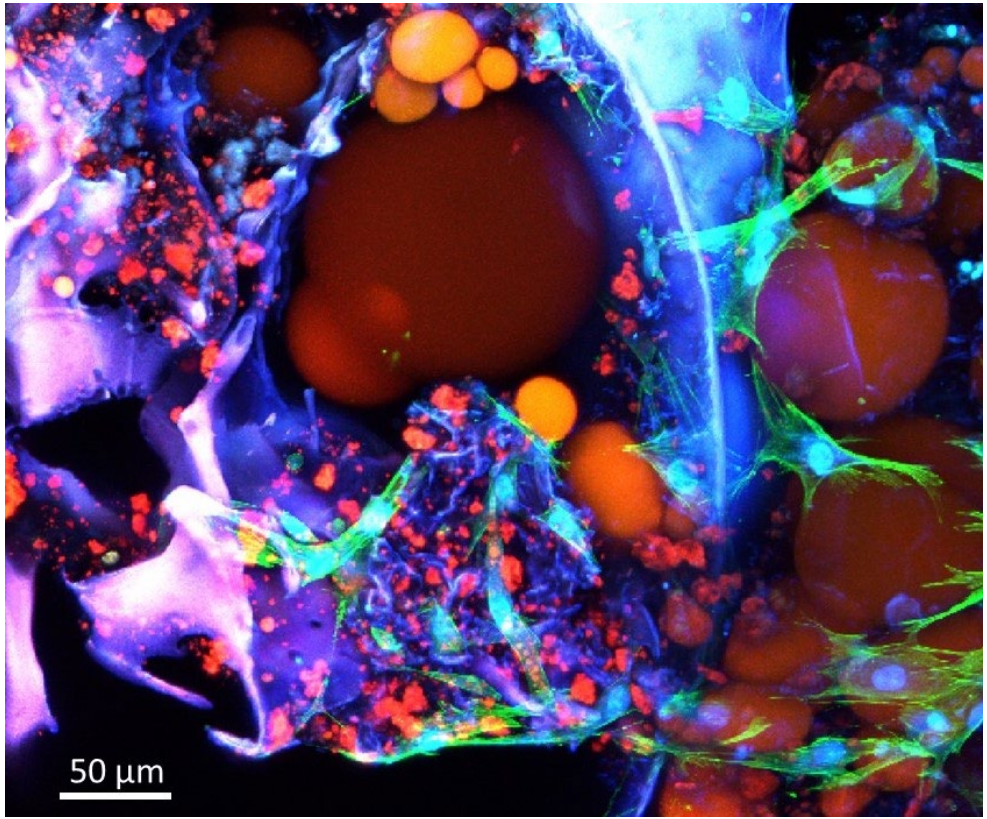
Example 1: Adipose Microenvironments



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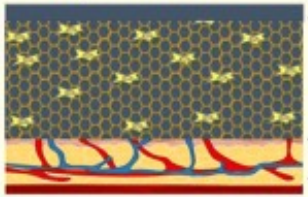
Example 2: Wound-Healing Biomaterials

a

Dermal skin substitutes

Autologous dermal skin substitutes

Hyalomatrix®



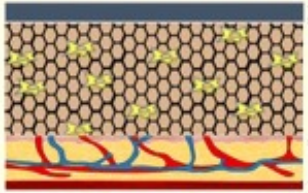
Silicone membrane

Patient fibroblasts
Hyaluronic acid scaffold

Injured skin

Allogenic dermal skin substitutes

TransCyte™



Silicone membrane

Neonatal fibroblasts
Collagen coated scaffold

Injured skin

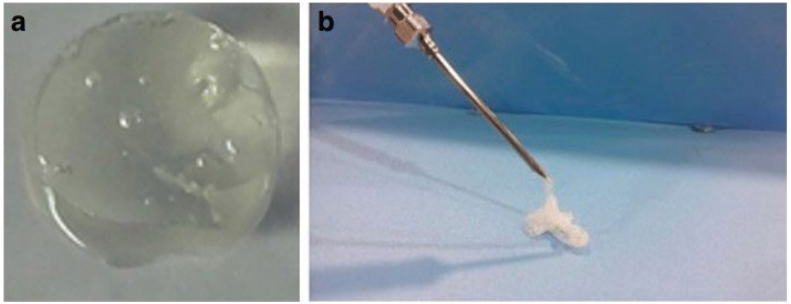
b

Epidermal skin substitutes

Autologous epidermal skin substitutes

Epicel™

Autologous keratinocytes



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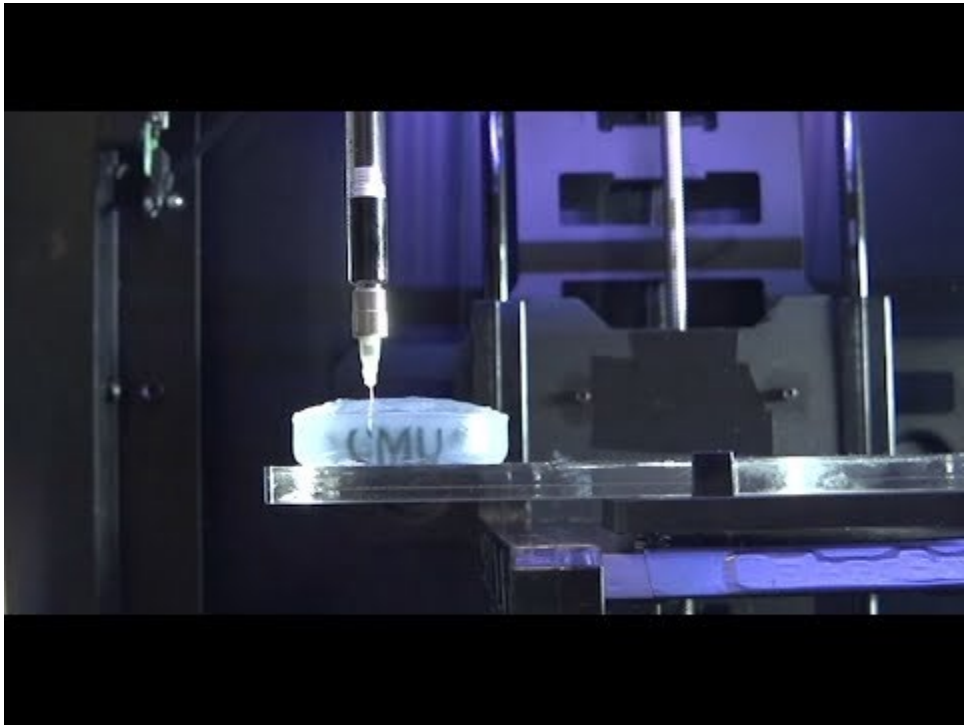
CMU Connection: Regenerative Biomaterials and Therapeutics Group



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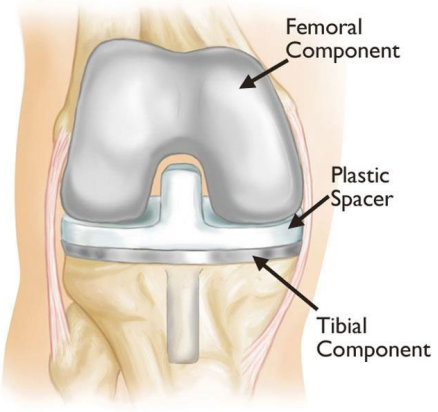
Biomedical Devices

Focus Area: Biomedical Devices

The field of study that produces instruments, machines, implants, in vitro reagents, software, materials, and other related articles for the safe and effective prevention, diagnosis, treatment, and rehabilitation of illness and disease for human beings

- What you study
  - Instrumentation and measurement
  - Diagnostic vs. therapeutic devices
  - Integrated Systems technology
  - Device fabrication
  - Interaction with cells, tissues, organs



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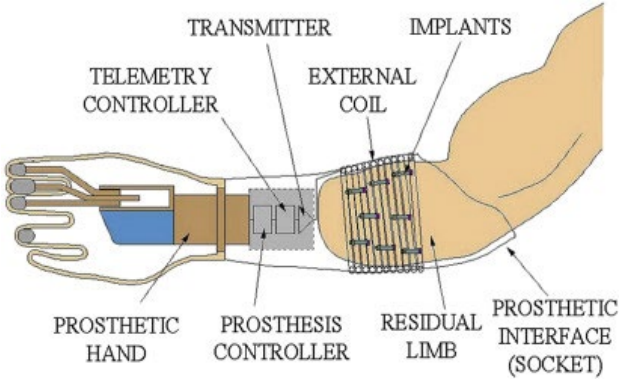
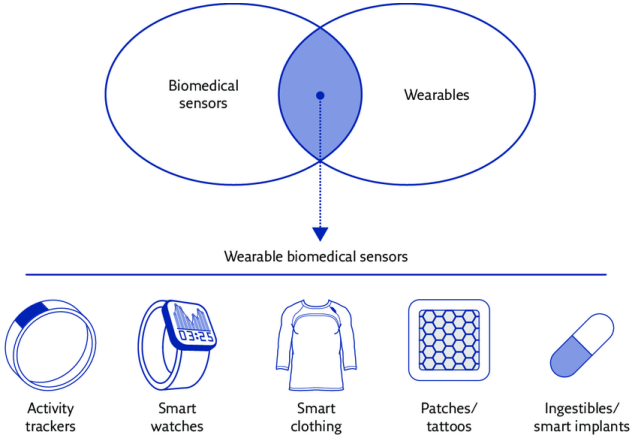
Applications: Biomedical Devices

- Sensors
- Actuators
- Diagnostic devices
- Therapeutic devices
- Instruments
- Systems
- Software





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Example 1: Implantable Heart Pump

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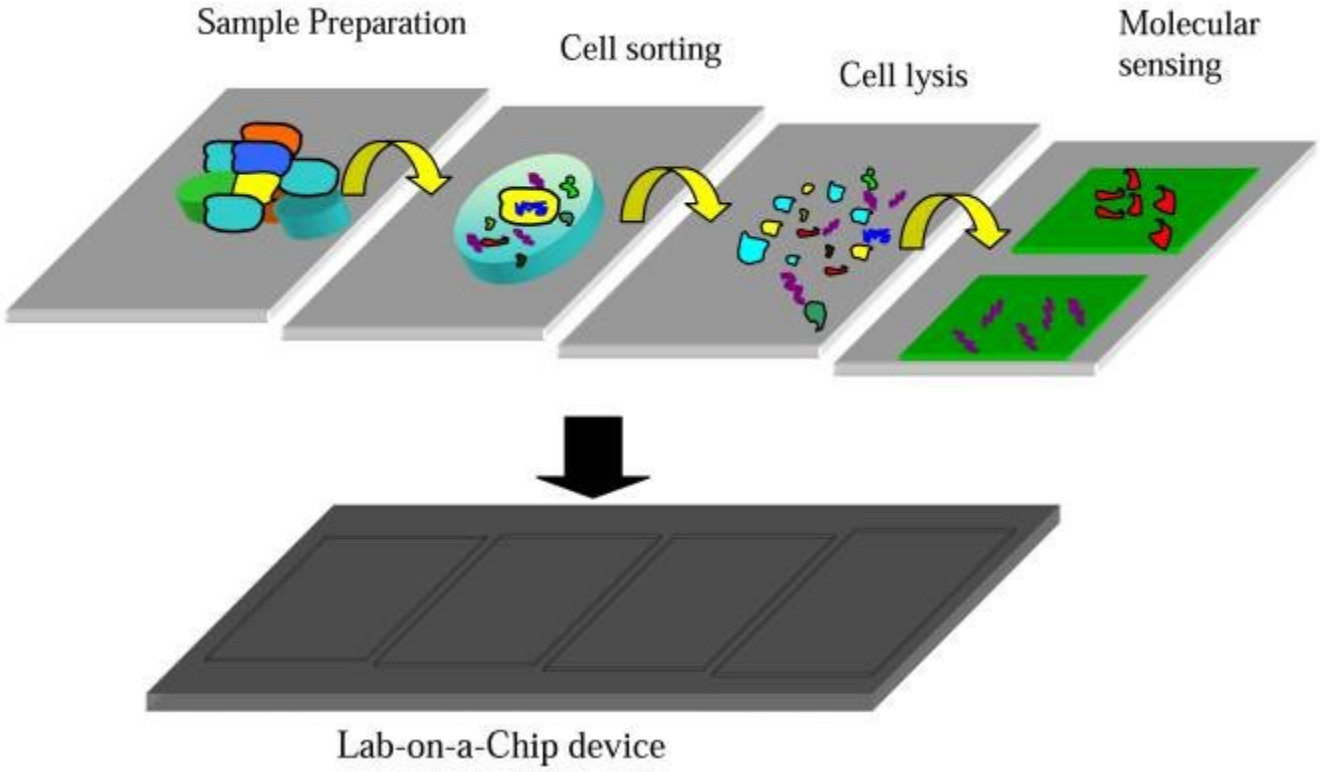
Example 2: Lab on a Chip (BioMEMS)



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CMU Connection: Ingestible Medical Devices

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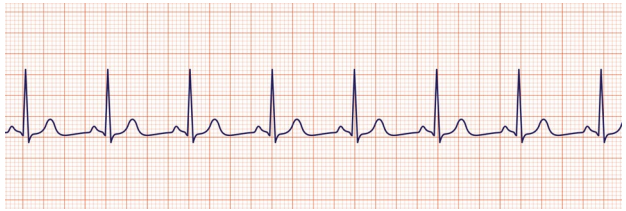
Bioimaging and Signal Processing

Focus Area: Bioimaging and Signal Processing

The field of study centered on methods and instruments used to acquire, process, and visualize structural or functional images of living objects or systems at desired spatial and temporal scales



- What you study
  - Medical imaging
    - Methods
    - Types
  - Signal processing
  - Image analysis
  - Neural engineering
  - Electrical signals of brain and heart

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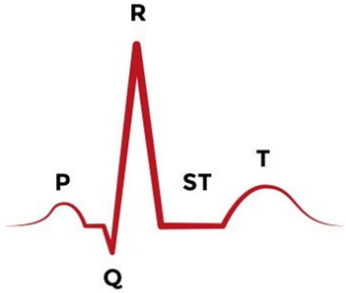
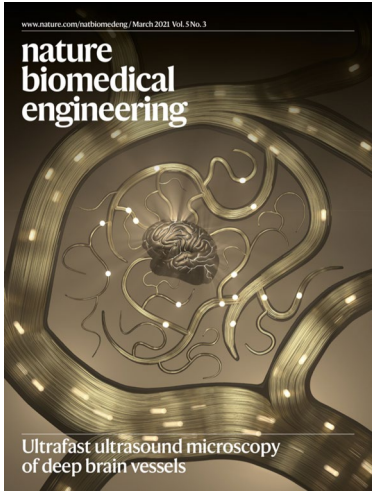
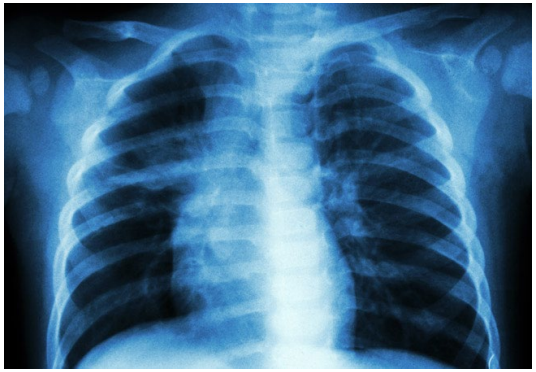
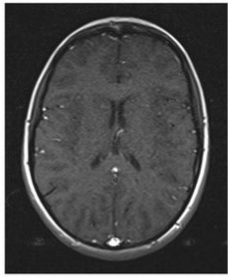
Applications: Bioimaging and Signal Processing

- Electrocardiograms
- Neuron functions
- Heart functions
- Imaging modalities (microscopy, ultrasound, X-ray, CT, PET, MRI, etc.)
- Image qualities (contrast, signal, spatial resolution)

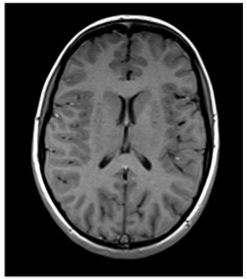




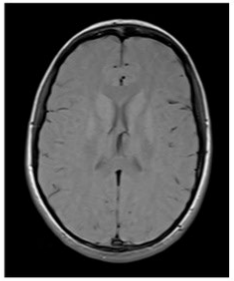




TR 200
TE 15
Low tissue contrast
Low SNR



TR 500
TE 15
High tissue contrast
High SNR



TR 1000
TE 15
Low tissue contrast
High SNR

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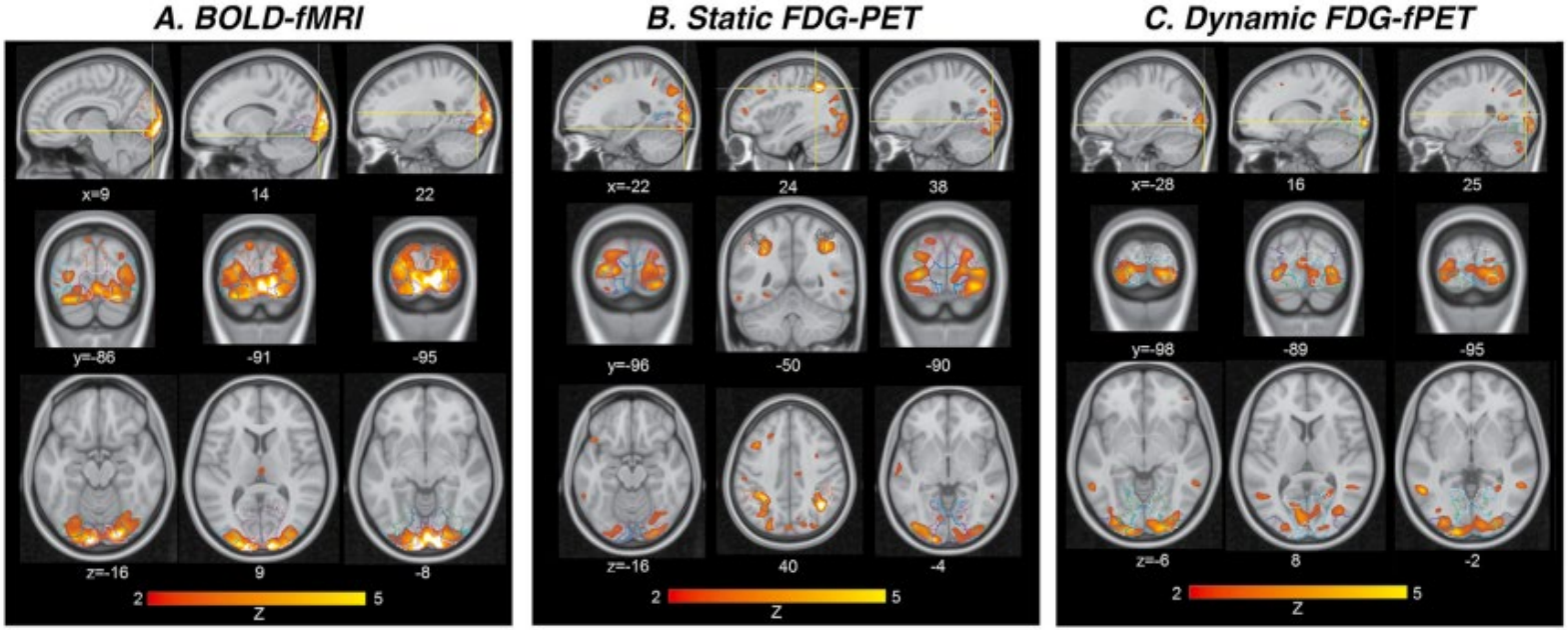
Example 1: Simultaneous BOLD-fMRI and FDG-PET



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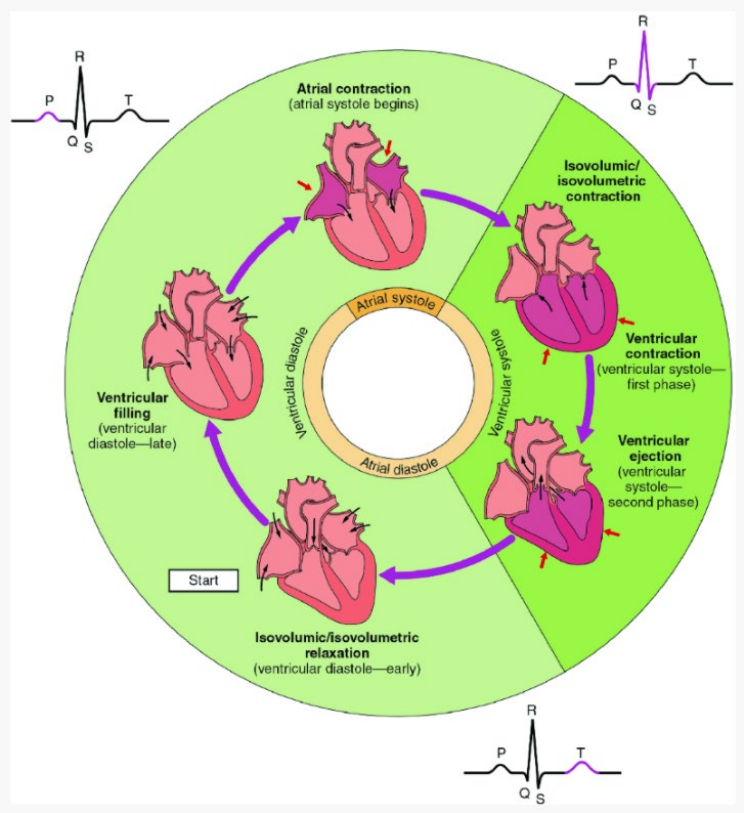
Example 2: ECG Signals



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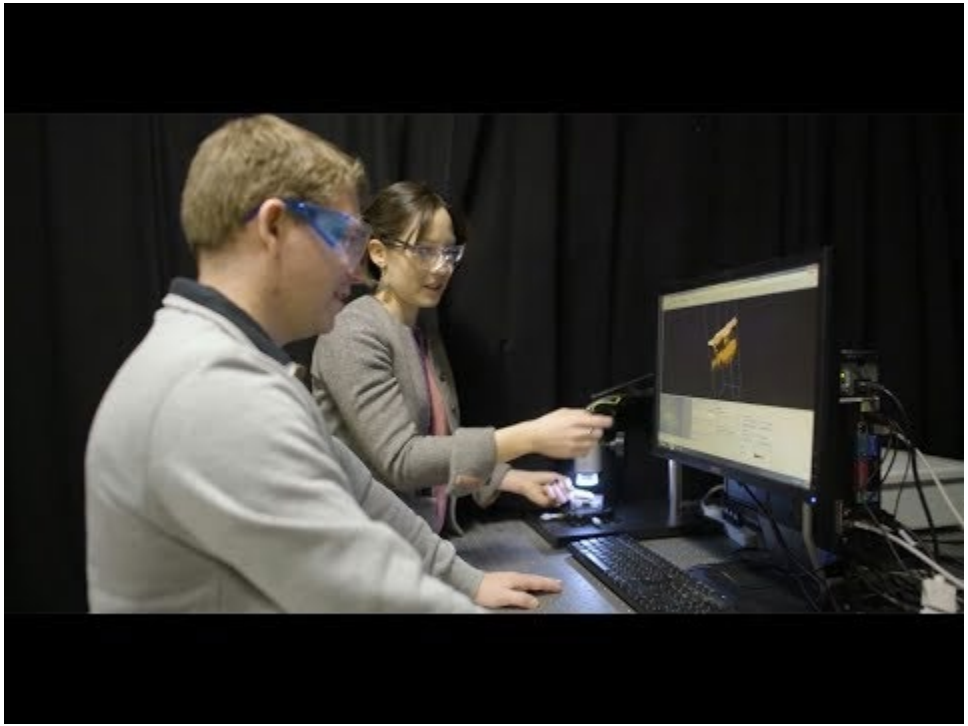
CMU Connection: Biomedical Optics



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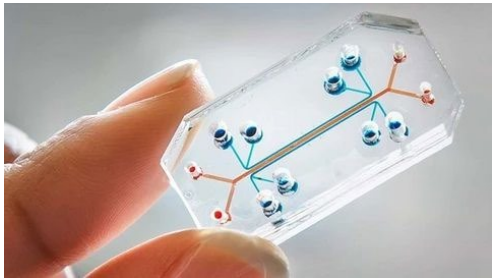
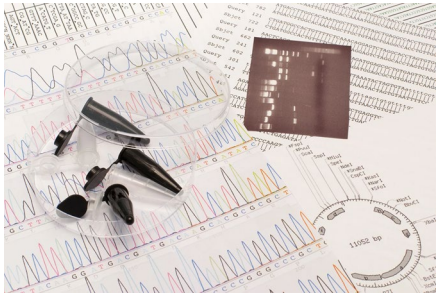
Cellular and Molecular Biotechnology

Definition & Scope: Cellular and Molecular Biotechnology

The field of study focused on the practical application of cellular and molecular knowledge with the aim of enhancing or improving production in microorganisms or cell cultures

- What you study
  - Biological regulation (signaling, endocrine system, hormones)
  - Cell culture
  - Cell morphology
  - Genetics
  - Diffusion, transport, and delivery
  - Binding kinetics





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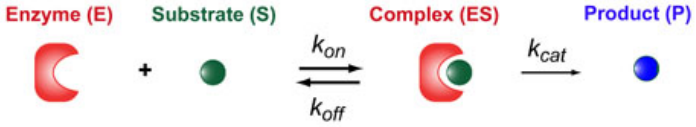
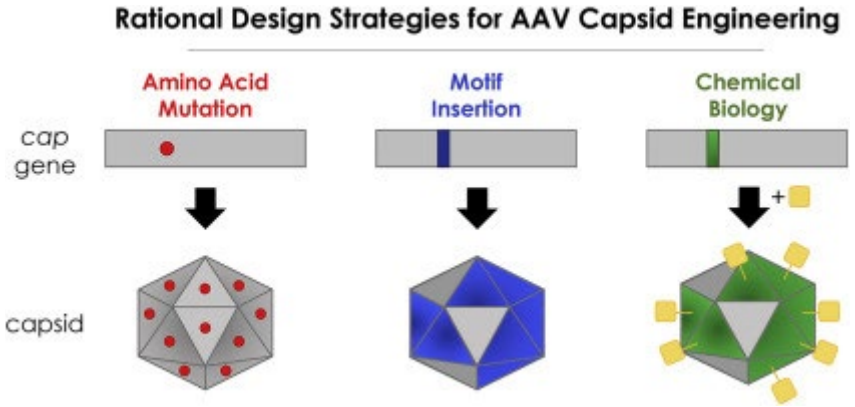
Applications: Cellular and Molecular Biotechnology

Protein manufacturing

- Pharmaceuticals
- Virus manufacturing
- Genetic engineering
- Vaccines
- Bioreactors
- Microfluidics





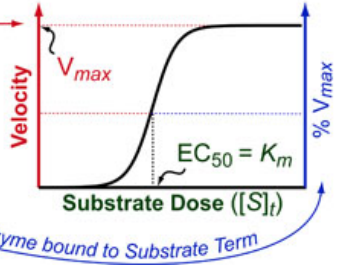
Michaelis-Menton Equation

$$\frac{d[P]}{dt} = k_{cat}[E]_t \cdot \frac{[S]_t}{K_m + [S]_t}$$

Maximum Velocity Term

Fraction of Enzyme bound to Substrate Term

Dose-Velocity Curve



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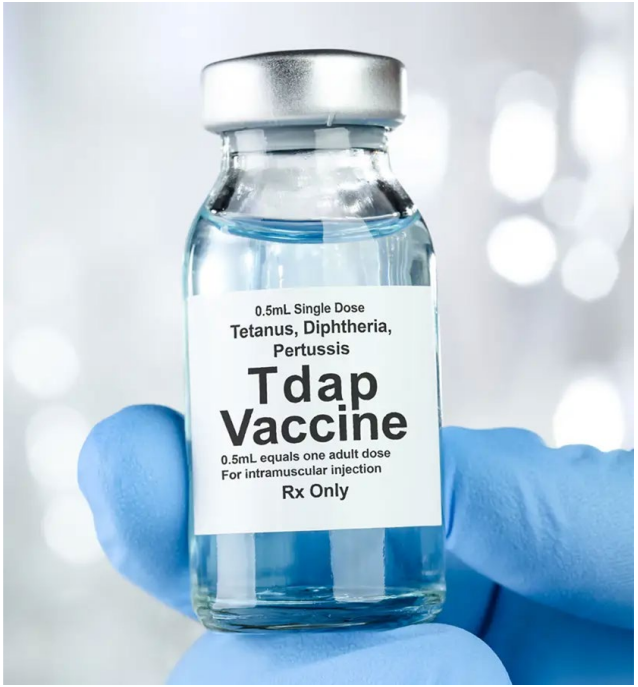
Example 1: Vaccine Development



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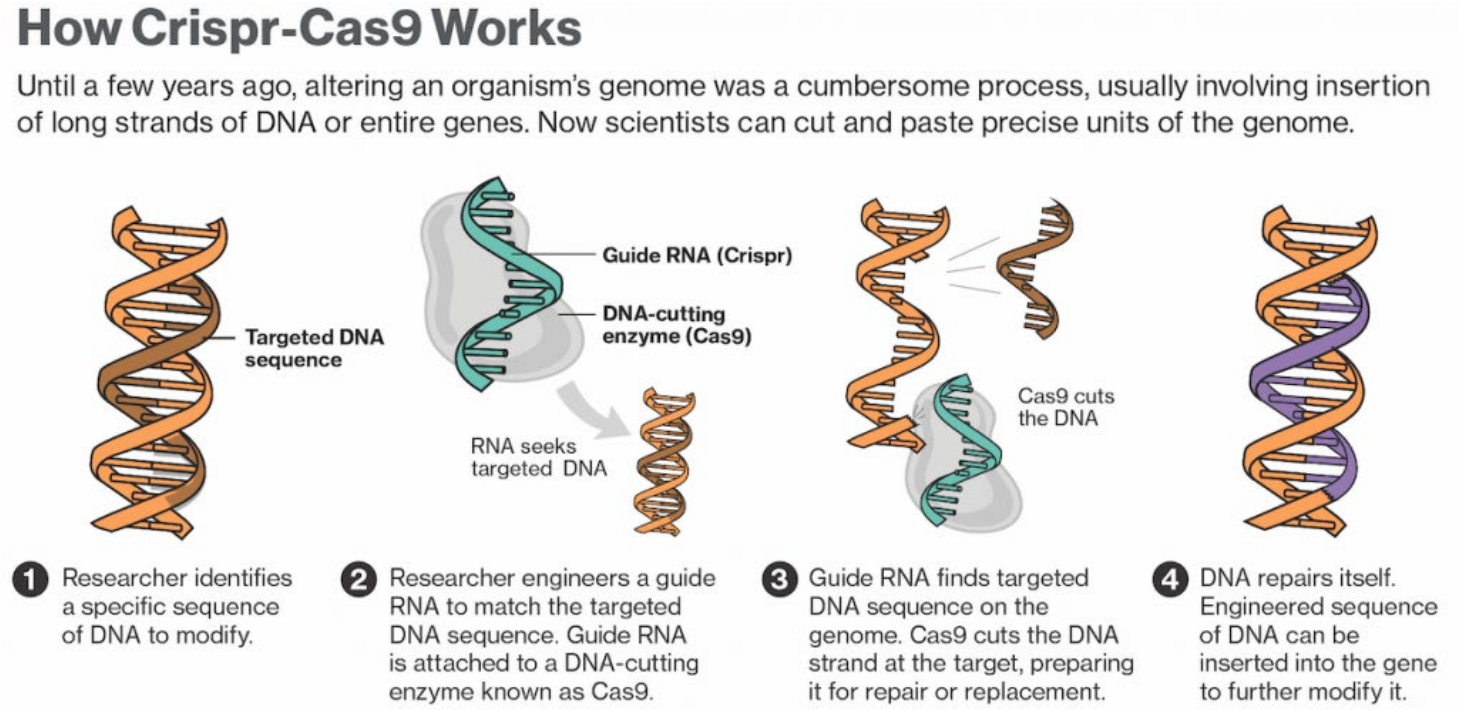
Example 2: CRISPR Gene Therapy



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CMU Connection: mRNA Drug Delivery

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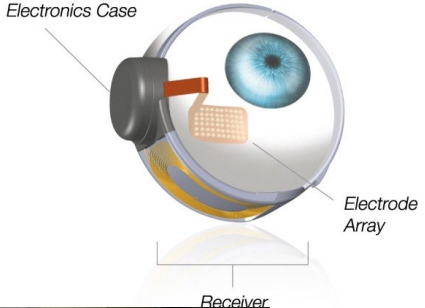
Neuroengineering

Focus Area: Neuroengineering

The field of study that involves the use of engineering technology to study the function of various neural systems

- What you study
  - Neuroimaging techniques
  - Neural anatomy
  - Action potentials
  - Nervous system modulation



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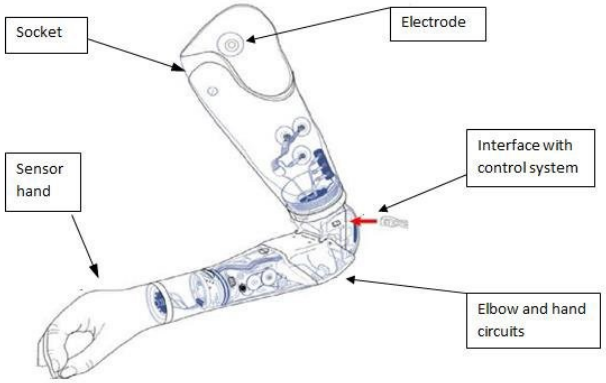
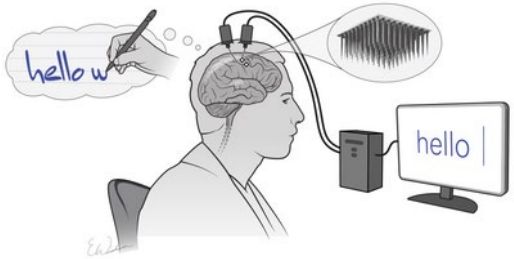
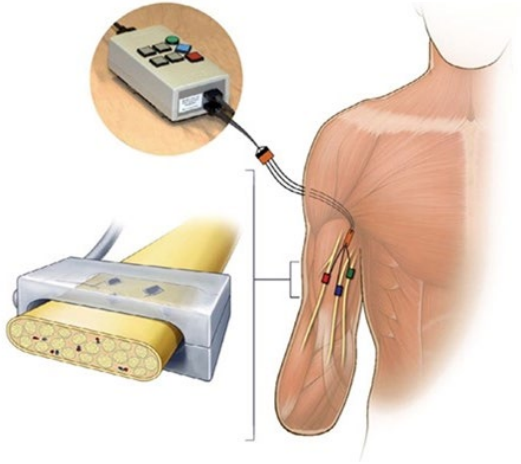
Applications: Neuroengineering

- Implantable technology and materials
- Neural prosthetics
  - Cochlear implants
  - Retinal implants
  - Touch restoration
  - Vestibular implants
  - bladder/bowel control
  - Brain-computer interfaces
- Sensor and motor prosthesis







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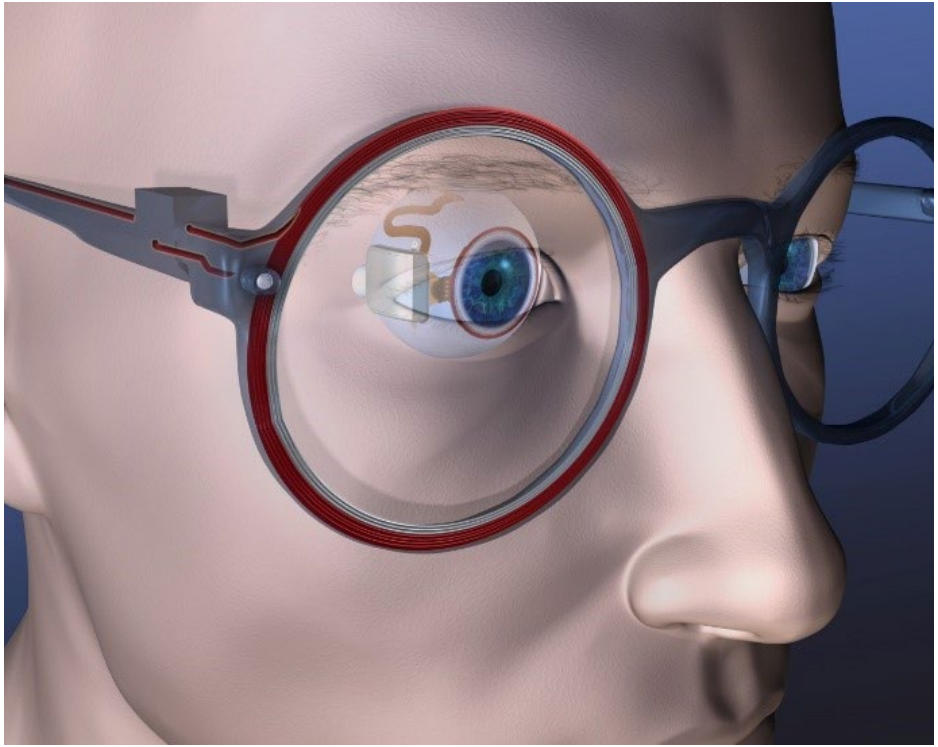
Example 1: Retinal Prostheses



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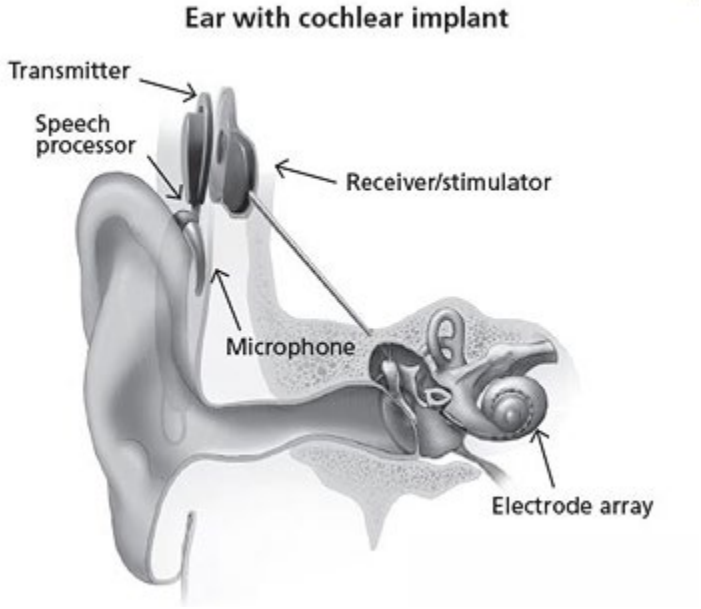
Example 2: Cochlear Implant



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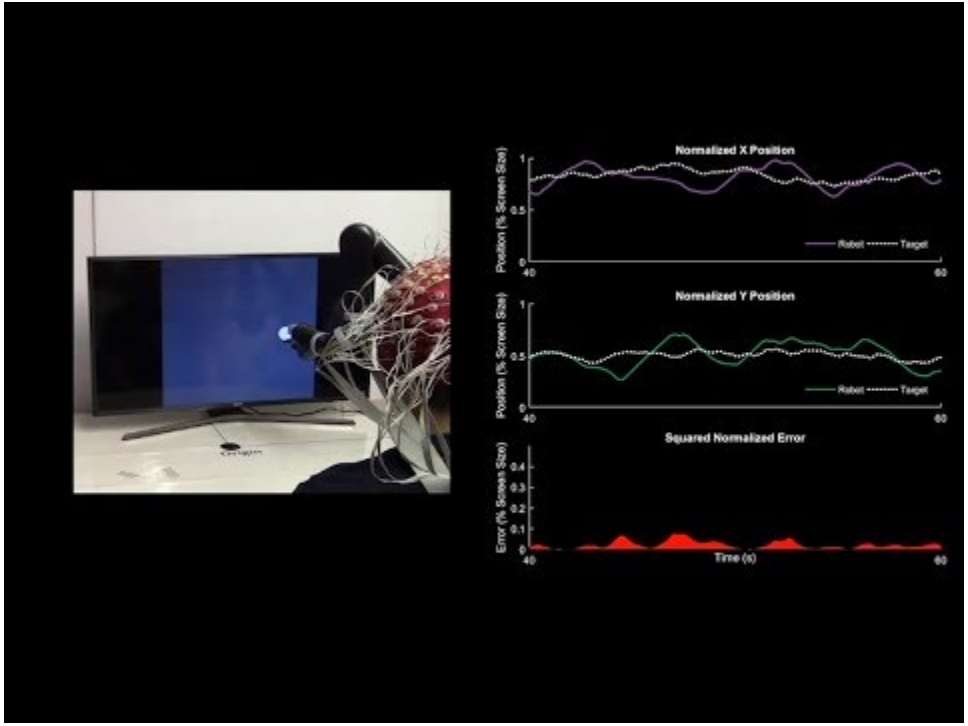
CMU Connection: Non-Invasive Mind-Control of Robotic Limbs



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Wrapping Up

Looking Forward: Unanswered Questions in BME

- Personalized medicine
- Artificial organs
- Human-Machine interfaces
- Artificial Intelligence
- Better understanding of medical conditions
- Ethical considerations

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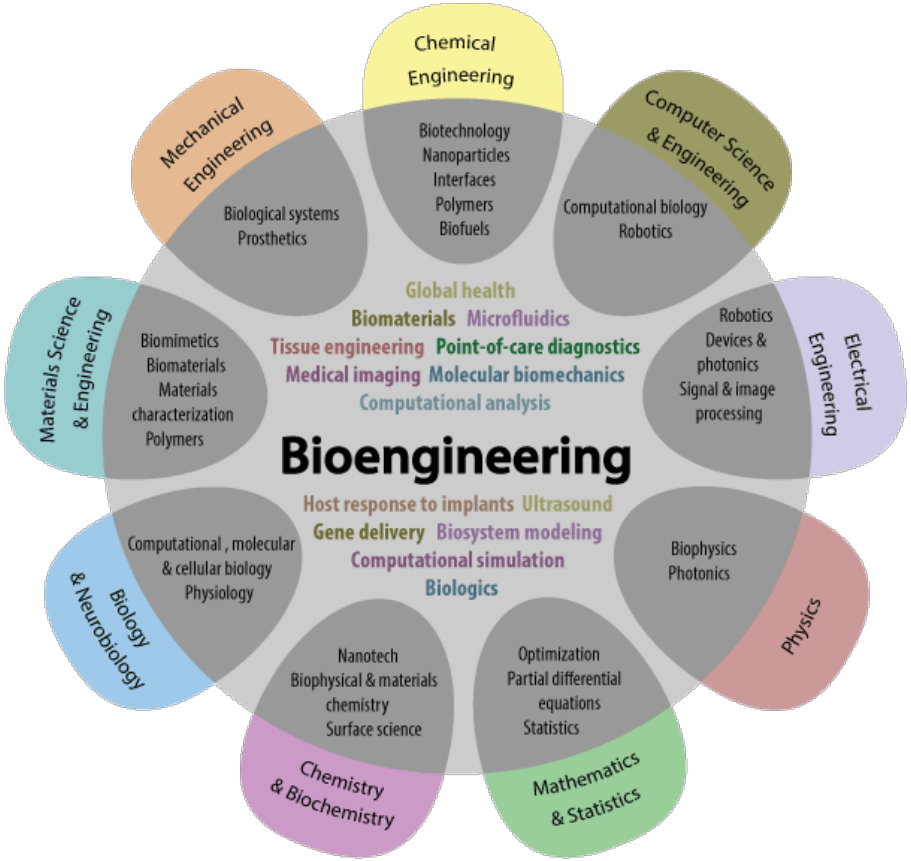
You may like more than one of these focus areas… and that's okay!



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