42-101 Intro to BME

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Great Achievements in Medical and Biological Engineering

1950s and Earlier
- Electrocardiogram (EKG/ECG)
- Artificial kidney (Dialyzer)
- Adhesive bandage
- Insulin delivery (extraction, sensors, pumps)
- Cardiopulmonary Bypass
- Blood handling and fractionating
- Plastic contact lens
- X-ray
- Cardiac pacemaker
- EEG
- Antibiotic production technology
- Defibrillator
- Geiger counter
- Iron lung

1960s
- Balloon catheter
- Gamma camera
- Vascular stents
- Biomedical telemetry
- Heart valve
- Respirator
- Intraocular lens
- Electronic hearing aids
- Dental implant
- Ultrasound
- Scanning electron microscope
- CPR
- Automated blood analyzer
- Vascular grafts
- Seat belts

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# Great Achievements in Medical and Biological Engineering

## 1970s
- Computer assisted tomography (CT)
- Biological plant engineering (Green Revolution)
- Immunoassay Systems
- Neurological electrical stimulation
- Cochlear implant
- Powered wheelchair
- Sutures (staples, resorbable)
- ICU monitoring (adults/infants)
- Clinical use of computers
- Auto safety testing
- Endoscopy (Eliminate exploratory surgery)
- Total joint replacement (hip/knee/ankle)

## 1980s
- Artificial heart
- Ventricular assist devices
- Drug delivery systems
- Imaging agents
- Laser surgery (eye, esthetic, therapy)
- Biosensors
- Magnetic resonance imaging
- Pulse oximeter
- Microcatheter (steerable guidewire)
- ECMO (pediatric)
- Safe food processing
- Microinvasive surgery
Great Achievements in Medical and Biological Engineering

1990s and Forward
Image-guided surgery
Drug eluting stents
Tissue engineering (scaffolding/electrospinning)
Human genome (sequencing/microarrays)
PET Scan
Automated protein identification
Integrated pacemaker/defibrillator
Production of therapeutic proteins
Digital image archiving
Intelligent medical search (web access)
Swallowable diagnostics
Implantable neural stimulator
Bioremediation
NLM Visible Human Project

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Hip Joint Replacement

- Total hip replacement “one of most successful surgical procedures” according to NIH (1994).
- 168,000 per year
- First performed in 1930’s
  - Unsuccessful due to infection, poor fit, bone wear
- Improvements
  - 1960’s: reduced friction by decreasing size of ball joint, improved stability using poly(methylmethacrylate) adhesive
    - Use of Teflon cup – but Teflon wear harmed surrounding tissue
    - High molecular weight polyethylene provides wear-resistant, durable implants.
  - New research underway with porous hydroxyapatite coatings for cement-less implant fixation
Magnetic Resonance Imaging

F-6y, Coronal chest and neck, 24 cm FOV, 79.8 mm Thk, GE(30o), TR/TE = 6.4/1.4 ms, 1 Nex, 256x160 matrix

http://www.cis.rit.edu/htbooks/mri/inside.htm
Magnetic Resonance Imaging

Axial head, 22 cm FOV, 256x224 matrix

http://www.cis.rit.edu/htbooks/mri/inside.htm
Magnetic Resonance Imaging

- 1952 Nobel prize in physics to Bloch and Purcell for nuclear magnetic resonance
- MRI: non-invasive imaging without dyes or harmful x-rays
- Applies magnetic fields and detects radio waves emitted by atoms
  - Radio emission depends on local chemical environment
  - 1970’s discovery: Local environment varies from one tissue type to another, including cancerous vs. non-cancerous tissue
  - 1980’s: used to visualize abnormalities in brain and upper spine
- Problems: long times required to image, breathing and heart beat interfered with chest imaging
- Solution: High field magnets
- Today: MRI can discriminate tissues based on water content, iron, fat, blood; can image blood flow, cerebrospinal fluid flow
- Research:
  - Functional imaging (local metabolism in tissues) to diagnose source of Parkinson’s, epilepsy…
  - MRI-guided surgery
Heart Pacemaker

• Originated in 1950’s
  – First device was large, required wall outlet – caused shocks, blackouts a problem
  – 1957 Medtronic develops wearable, battery drive, book-sized pacemaker with electrode directly wired to heart
  – Problems with wires for long-term application, including infection and dislodging.
• VA Hospital in Buffalo develops miniature pacemaker following accidental use of wrong resistor in new heart-beat monitoring device – led to first totally implanted pacemaker with corrosion-resistant battery, technology licensed by Medtronic

• Advances: more efficient electrodes with better adhesion, “intelligent” devices with heart monitoring and feedback, long-life (10 years) lithium batteries.
• Today pacemakers weigh 0.5 oz., measure 1 inch in diameter.
Angioplasty

- 1977, Swiss physician inserted catheter into coronary artery to inflate a balloon to clear blockage
  - Minimally invasive, mechanical solution to medical problem.
  - Problems; rapid re-closure of vessel

- Balloons now used to expand stents that are left behind.

- Problems: Restenosis (immune response to stent surface, producing scar tissue buildup).

- New research – stent coatings that release clot-deterring compounds, new biocompatible materials.

- Today > 1 million balloon angioplasties per year
  - World’s most common medical intervention

from American Heart Association
http://circ.ahajournals.org/cgi/content/full/105/22/2586

from http://www.uni-heidelberg.de/presse/news/2310chem1.html

E.coli resistant Polyzene® - F Matrix
Bioengineered Skin

- Early success of tissue engineering to treat burn victims
- 1977 FDA approves Advanced Tissue Sciences’ TransCyte® as temporary wound cover
  - Human dermis with synthetic epidermis – blocks fluid loss, reduces infection until skin regrows (2nd degree) or surgical skin graft (3rd degree)
- 1998 FDA approves Organogenesis’ Apligraf® synthetic skin for diabetic ulcers
  - Bovine collagen + human skin cells in base layer; epidermis formed by prompting keratinocytes (skin cells) to differentiate to mimic human skin.
- In U.S. 1500 burns requiring grafts, 40,000 2nd degree burns per year; 800,000 with diabetic foot ulcers requiring 80,000 amputations per year.
Kidney Dialysis

- Use of semi-permeable membrane to extract wastes from blood
- 300,000 with chronic kidney failure in U.S.
- 1940’s, Willem Kolff M.D. develops artificial dialysis
  - War-related shortage of membrane materials
  - Biochemist at Groningen University shows that cellophane sausage casing can be used as a membrane to exchange compounds between two liquids.
  - Prototype made of wood slats, orange juice cans and washing machine.
- Baxter Laboratories introduces first commercial dialysis machine in 1956.
- Novel techniques:
  - Peritoneal dialysis uses peritoneal sac around abdominal organs as membrane, dialysis fluid injected into abdominal cavity; can be done at home
  - Ambulatory peritoneal dialysis – pump meters dialysis fluid into abdominal cavity while patient sleeps.
Heart-Lung Machine

• Device to pump and oxygenate blood during open heart surgery
  – Unoxygenated blood pumped from upper heart chambers to reservoir, then to “artificial lung” where blood absorbs O$_2$, then filtered to remove bubbles and pumped back into patient’s aorta

• Enables 750,000 open heart surgeries per year
  – Prior to 1950, open heart surgery was impossible

• Invented by John Gibbon in 1937 at Jefferson Medical College, Philadelphia
  – Two roller pumps
  – Problems with blood damage, infections, air bubbles

• 1945 Swedish group of scientists and chemical engineers developed rotating disc, film flow oxygenator with blood filter

• Modern devices allow for several hours of operation and control temperature (allows low T surgery)

• Risks still exist from blood clot formation and inflammation – motivates biocompatible materials research.

http://www.texasheartinstitute.org/hsurg.html
The Five BME Foci

Biomedical Image and Signal Informatics
Regenerative Medicine
Computational Biomechanics & Devices
Medical Robotics
Molecular & Cellular Biotechnology
Murphy: Location Proteomics

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Hollinger: Repair of Craniofacial Bone Deficits
Antaki, Ghattas: Pediatric Ventricular Assist Device
Weiss: *In situ* Printing of Tissue Scaffolds
Przybycien, Hauan, Fedder/Gabriel: Acoustic Membrane Biosensor