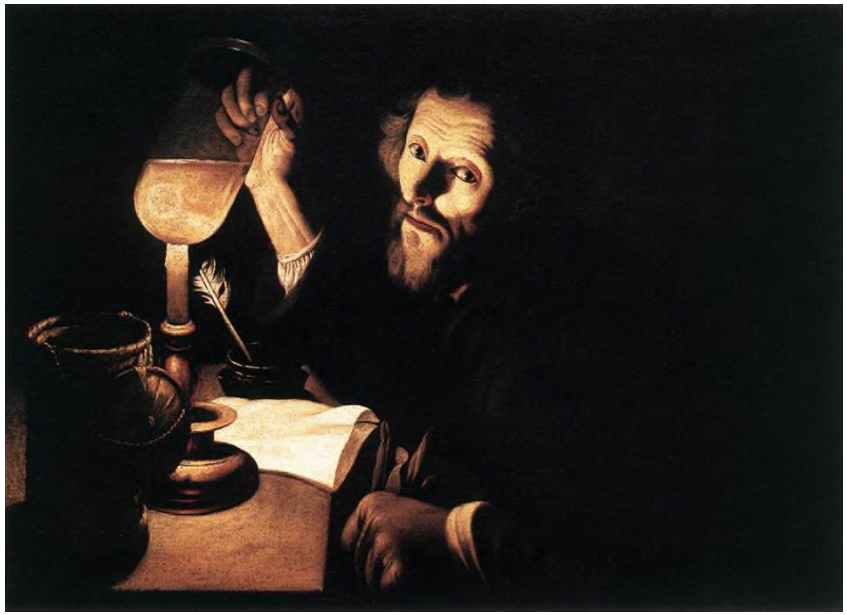
# ECE 370
# Introduction to Biomedical Engineering

## Introduction - History

## Which is the most basic “technology” in medical diagnosis?

# The most basic medical “technology”

- **The patient!**
  - Description/History = Diagnosis
- **The Senses!**
  - Vision (visual survey)
  - Hearing (heart, lungs, abdomen)
  - Touch (palpation, pulse)
  - Olfaction (patient, mouth, stool, urine)
  - Taste (urine)
    - Important diagnostic method until the 20th century
  - Important tests still today

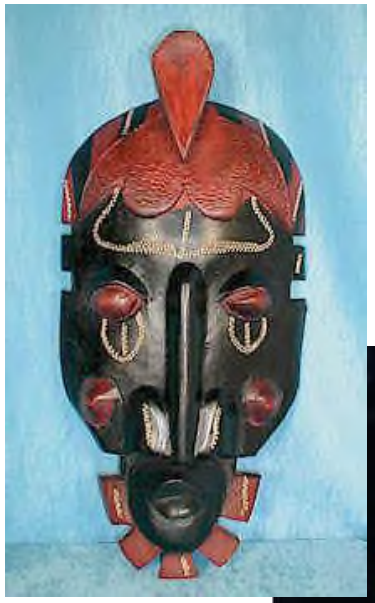


**A Doctor Examining Urine**
(Oil on canvas, Ashmolean Museum, Oxford)
**BIGOT, Trophîme**
French painter (ca. 1600 - 1650)

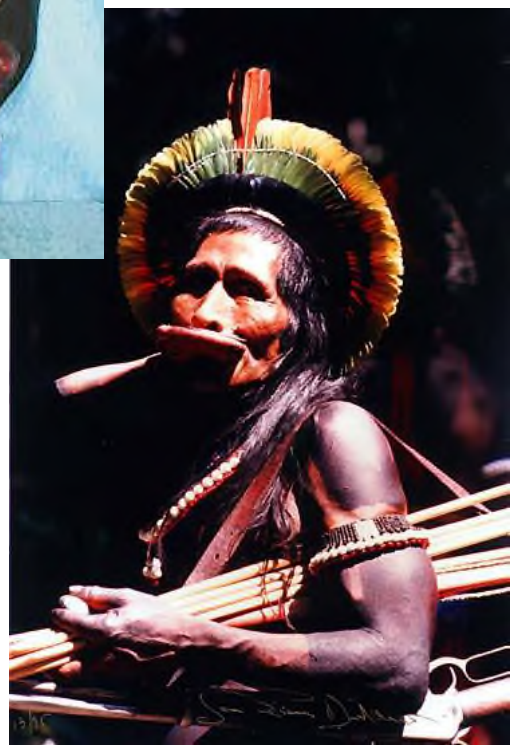
# How ancient is medical technology?

# The “medicine man”

- **Prehistoric times**
- **Diseases caused by spirits and demons**
- **Doctor = Wizard = High Priest**
- **Treatment**
  - Purification
  - Appeasement
  - Intimidation and expulsion
- **Technology**
  - Spells
  - Idols
  - Masks, leathers and colors
  - Herbs
  - Surgeries!
- **Exist even today in primitive societies**



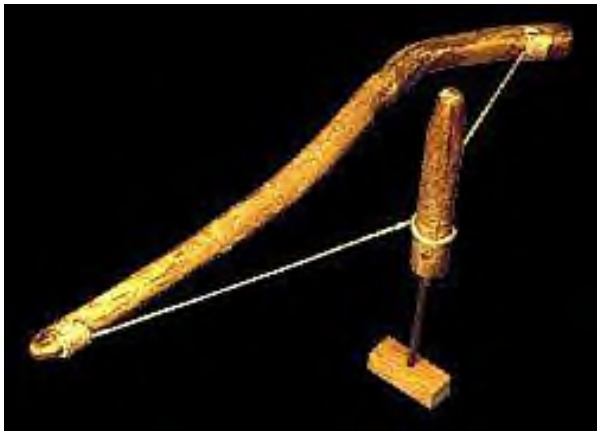
**Amazon**

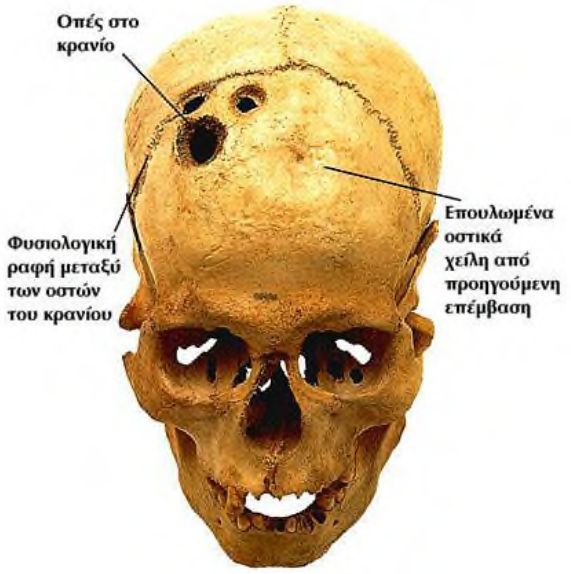


**Kenya**

# Prehistoric Technology

- **First neurosurgical operations: Trephination (20,000 BC)**
  - Removal of evil spirits?
  - Epilepsy?
  - Mental Disorders?
  - Migraines?
- **Latest in Technology**
  - Drills with a wooden handle and sharp edge
  - Bow drill
- **Some of the patients survived!**
- **It is still performed today!**





# When did the first medications and first surgical procedures appear?

# Mesopotamian medicine

- **Assyrians, Sumerians, Babylonians (Mesopotamia, 3000 BC)**
- **Egyptians (1500 BC)**

- **Medical Science**
  - Herbal medicines (usually ineffective)
  - Surgery (catheterization for gonorrhea)
- **Medical-magic-religion**
  - Splachnomanteia
  - Spells
- **The seals of some doctors have survived**

*Build the figure with dough*
*Bathe with water and*
*After, using the water from the spell.*
*Bring a censer and a torch.*
*As the water flows away from the body*
*So evil will run away from the body.*

# Hammurabi

- The Code of Hammurabi also regulated medicine

- "If a doctor opens up a tumor of a free man with a metal knife and heals the eye, will be rewarded with ten silver coins. If the patient is the son of plebeians he will be rewarded with five silver coins. If the free man dies due to the handling of the doctor, both of his hands will be cut. If the doctor caused the death of a slave then he should replace him."

# Who were the first known doctors?

# The First Doctors

- **Seketenanak and Imhotep**
- **Imhotep (between 2700 and 2600 BC)**
  - Grand Vizier
  - Astrologer
  - Architect and builder pyramids
  - Poet
  - Pathologist of the Pharaoh
  - The first proctologist ("Shepherd of the anus")
- **Later worshiped as a healing deity and merged with Asclepius (also deified doctor)**

# Asclepius

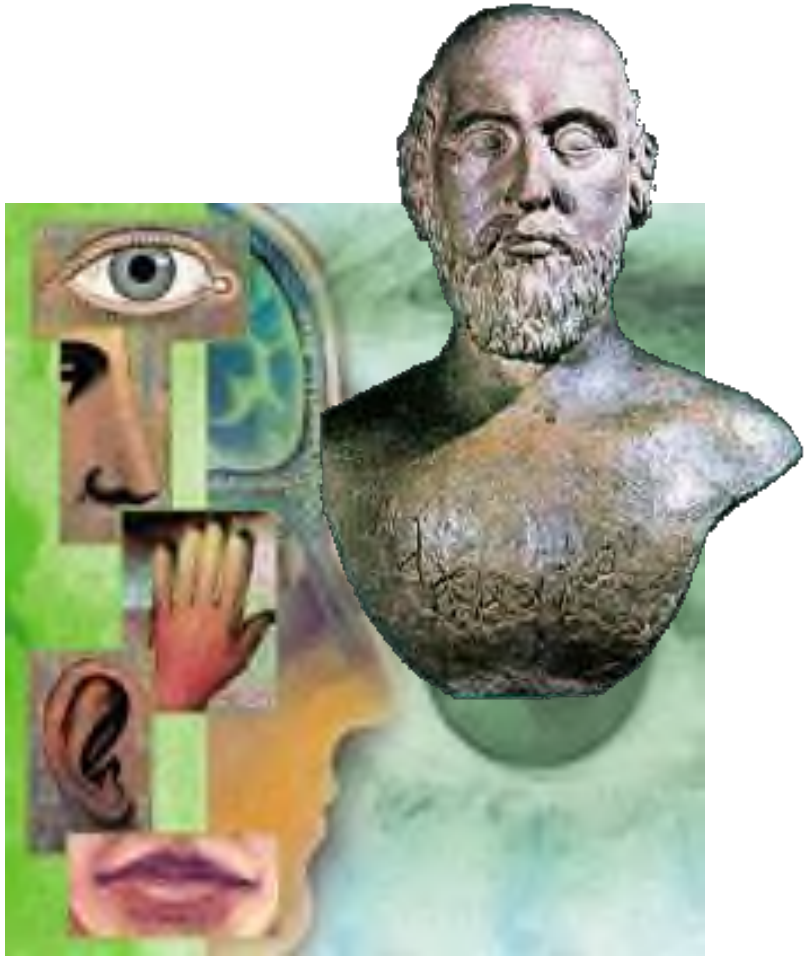
- **Diseases = punishment from the Gods**
- **People look to the gods for healing**
- **Asclepius (son of Apollo and Coronis)**
- **He learned medicine from the centaur Chiron**
- **Asclepion**
  - Temple of Asklepios at Epidaurus
  - Asklipion at Pergamon.
- **The staff and the sacred serpent of Asclepius**

## Medicine as a Science?

## Who was the first physician-scientist?

# Ancient Greece: Medicine as a Science

- **Medicine is taught in schools - philosophical centers (6th century BC)**
- **Alkmaion of Croton (disciple of Pythagoras)**
  - Anatomical relations of the sensory organs to the brain
  - The mind rests in the brain the functions of thought and memory take place.
- **The first doctor-scientist**



# Hippocrates

- **Hippocrates (460-377 BC)**
  - Disease
    - Imbalance of the bodily chymes
  - Treatments
    - Emetics, laxatives,  cupping
    - Mainly herbal medicines (mostly ineffective)
    - Diet, exercise, music and avoid excessive fatigue
    - Cauterization
    - Anesthetic action of opium and mandrake

- **Hippocrates believed in**
  - the power of nature to heal
  - the power of the body to heal itself
  - the influence of geography on diseases.

- Careful observation and recording of symptoms
- Prognosis
- Systematic medical training (men and women)
- The medicine of Hippocrates dominated European medicine for over two thousand years

# Medical Top Ten

**Which were the top medical breakthroughs?**

# 10. Radioactivity and Radiotherapy

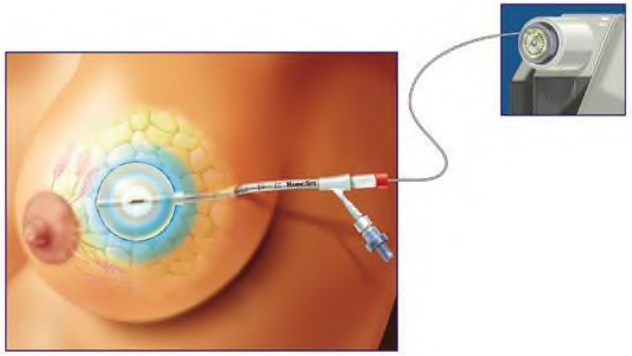
# Marie and Pierre Curie

- **Together they studied radiation (Becquerel 1896)**
  - Marie named it radioactivity
- **Radium and polonium, 1902**
  - tons of uranium ore
  - radioactive properties in the treatment of malignant tumors
  - basis of radiotherapeutics
  - Nobel Prize in Physics 1903
- **Pierre was killed in a car accident while crosses the street**
- **Marie took his place at the Sorbonne**
- **Nobel Prize in Chemistry, 1911.**
- **She died of anemia, probably due to the effects of radioactivity, 1934**

- 1st woman with a degree in Physics from the Sorbonne, 1893
- 1st woman who taught there in 650 years of history
- 1st person with two Nobel prizes
- 1st person who died due to radiation?

# Modern Radiotherapy

- **Use of radiation ( usually X or γ ) for treatment of malignant tumors**
- **Irradiation by**
  - external radiation source
    - focus and crossing to guard healthy tissue
  - implantation of radioactive elements in the tumor
  - intravenous radioactive substances with selective uptake specific to the tumor cells
    - eg Radioactive iodine absorbed by the cancer cells thyroid gland
- **It acts mainly in cells undergoing division**
  - destroys malignant tumors which have high rates of replication

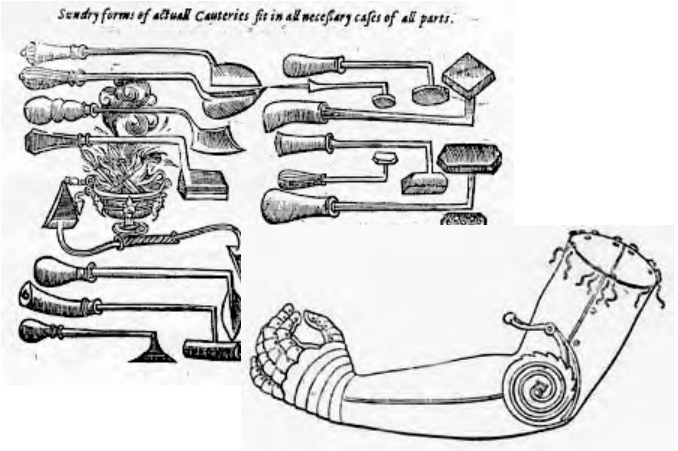


# 9. Surgery and Surgical Instruments

# Ambrose Pare

- **France (1517-1590)**
- **Progress in Surgery**
- **Without academic training**
  - started as a barber at the hospital of Paris
  - barbers during that era performed simple surgeries
- **He earned a great reputation as a military doctor**
  - revolution in the treatment of war wounds
  - replaced the use of hot oil by applying simple cleaning and bandaging
- **Inspirer and designer of surgical equipment and mechanical prostheses**
  - interventions in the eye
  - replacement of amputated extremities

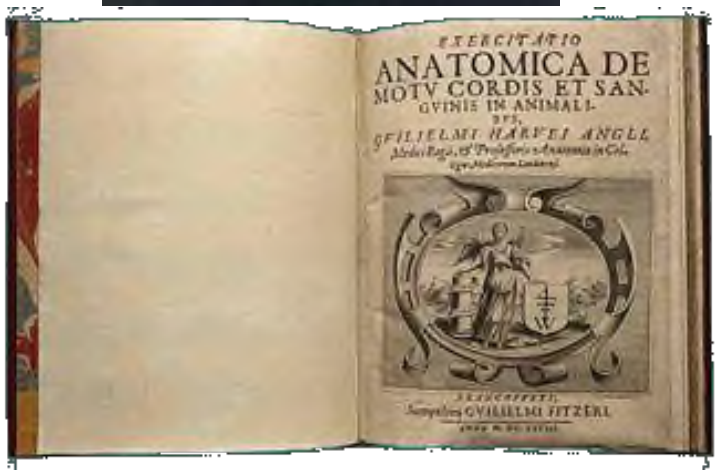




# 8. Blood Circulation

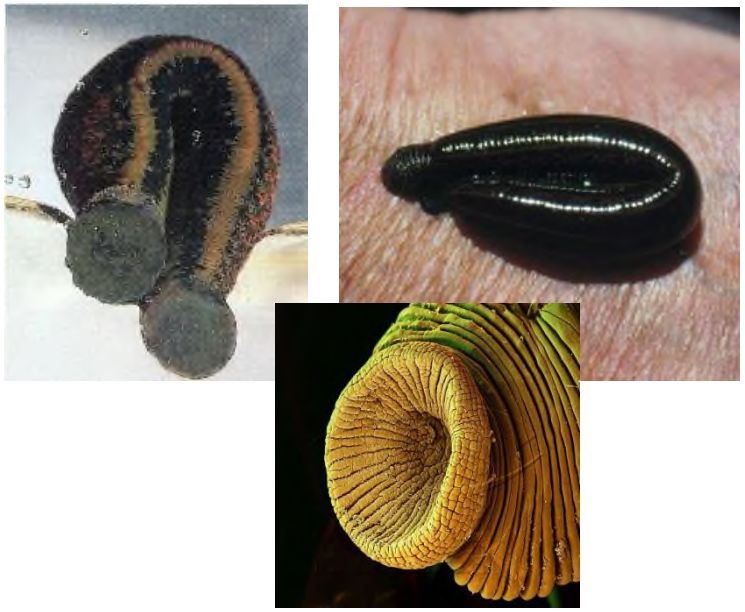
# Blood Circulation

- **Until the 17th century the dominating notion was that blood is synthesized by the foods in the liver and transported through the blood vessels to the tissues where it is consumed by them**
- **William Harvey (1628)**
  - blood circulates through the vessels
  - heart assumes the role of the pump
  - laid the foundation for a mechanistic view of the human body



# Blood Letting

- **Despite the medical advances in the 19th century, blood letting was still used**
- **Riddance of disease "poisons" and "evil spirits"**
- **The most popular method of blood letting (since ancient times) was using leeches**
- **In 1833 France imported 40 million leeches.**
- **In 1999, Turkey exported more than 800,000 medicinal leeches (80% of reported global sales.)**



*Hirudo medicinalis*

- Hirudin (protein, obtained from the leech Hirudo medicinalis) is a new specific inhibitor of thrombin

# Stethoscope

- **Auscultation of the heart and lungs**
  - The ear of the doctor was placed over the patient's chest
- **Renee Lenek (1781-1826)**
  - He did not want to put his ear to the chest of a young lady
  - Sheets of paper wrapped in a roll between the ear and the patient
  - Impressed by the result
  - Clearer sound
- **The first single (hearing in one ear) stethoscope built in 1816**
- **The double stethoscope built in 1850**

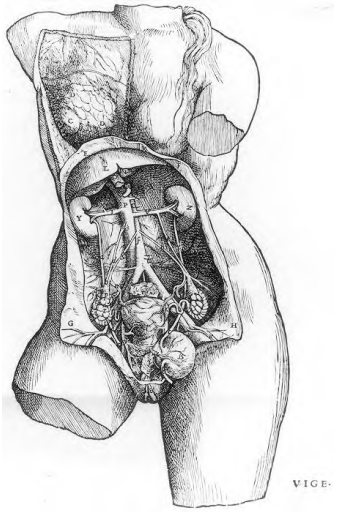
# 7. Anatomy

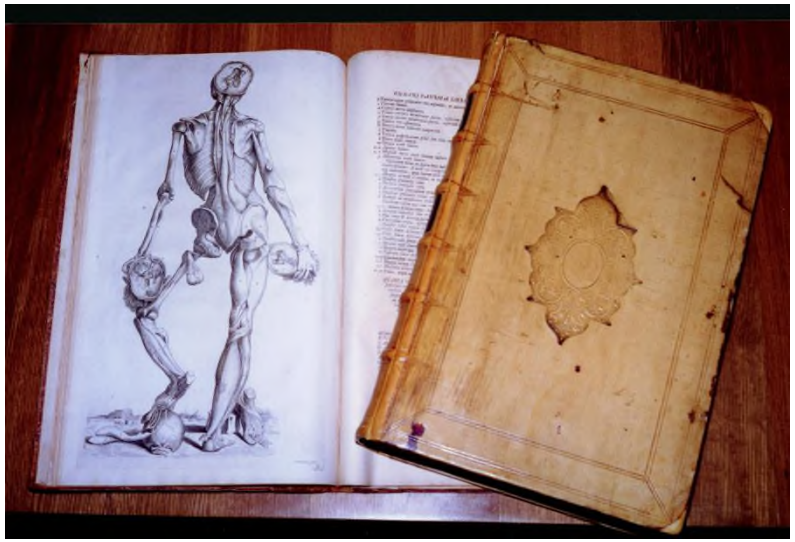
# Leonardo da Vinci

- **Brilliant and talented artist, scientist and theorist engineer**
- **Dissections of the human body**
  - Maxillary sinus and the fetus in the womb
- **He intended to create a major anatomical work**
  - the project was abandoned after the death of his artist partner

# Andreas Vesalius(1514-1564)

- **Born in Brussels in 1514**
- **Instructor of surgery and anatomy at Padua**
- **Published the monumental work, De humani corporis fabrika (On the construction of the human body) in 1514**
  - integration of splendid illustration
  - acclaimed as a fundamental anatomical textbook

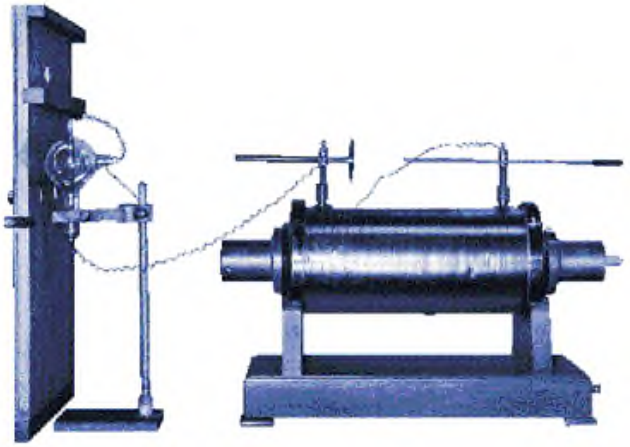




# 6. X-rays – Xray imaging

# X-Rays

- **Wilhelm Conrad Röntgen**
  - November 8, 1895
  - strong electric field in a vacuum bulb
  - saw a glow coming from the phosphor of the anode tube
  - left shadows on a photographic plate
  - rays were able to penetrate through even a wood table or a book of 1000 pages
  - won the Nobel Prize in Physics in 1901



# 5. Anesthesia

# Anesthesia

- **Pain management during surgery in the 19th century**
  - large amounts of alcohol
  - blows to the head until they fall unconscious
  - the lucky fainted from pain during surgery
- **Record: 30 sec for an amputation (surgeon in Napoleon's army)**
- **In 1816 the first public demonstration of surgical anesthesia took place**
  - using ether

# 4. Microbes and Asepsis

# Microbes and Diseases

- **The role of bacteria in causing disease**
  - unclear until the second half of the 19th century
- **Zemelvais and Lister linked bacteria to infections**
  - treated with incredulity
- **Preventive measures**
  - in wards and operating theaters
  - elementary cleanliness
- **L. R. Koch and Pasteur in the late 19th century established the "microbial theory"**
  - connection of specific microbes with corresponding diseases
  - developing methods for inducing immunity
  - manufacture of vaccines and antisera

# 3. Vaccination

# Prophylaxis from Smallpox

- **Attempted prophylaxis of smallpox, early 18th century**
  - fluid from patients' rashes as vaccine
  - method from the East (India, China) in the early 1000s
  - often led to contraction of disease
  - Gradually abandoned
- **Smallpox**
  - variola virus
  - Last appearance: Somalia 1977
  - Fever, malaise, headache, backache and muscle ache, vesicular and then pustular rashes


# Eduard Jenner

- **Smallpox Epidemic, 1796**
  - 60 million dead
- **Edward Jenner (England, 1749 to 1823)**
  - He founded the method of vaccination in 1798
  - Liquid from rashes of the milder cow pox (vaccination)
  - Vaccinated the son of his gardener who was at greater risk
  - After a short period infected him with smallpox
  - The child remained healthy

“vaccinate” from the latin

“vacca” = cow

# Vaccination

- **Improving the body's defense without causing disease**
  - Suitably sensitizing the immune system
  - Based on the memory capacity of the immune (defense) system
- **Using attenuated strains or sections of infectious micro-organisms (viruses, bacteria)**
- **Today most vaccines are chemically manufactured without use of the microorganisms**
- **In the case of an infection the body reacts efficiently**

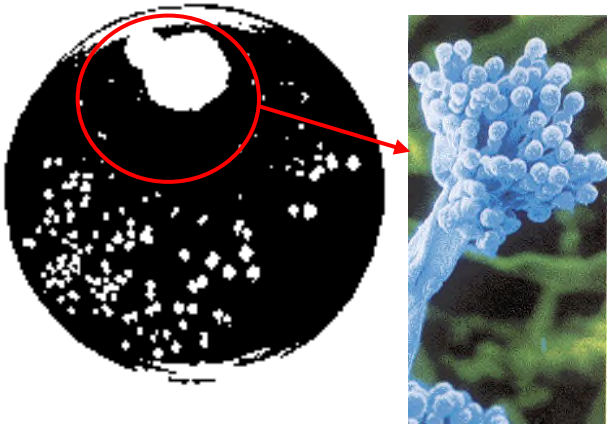
Why there is no vaccine for son HIV (AIDS)?

- constantly changing
- infecting the T cells of the immune system
- can be transmitted both free and within the T cells
- unknown how the body can fight this virus yet

# 2. Antibiotics

# Alexander Fleming

- **Bacteriologist**
- **His wife was the Greek physician and his assistant, Amalia**
- **One of the most important medical discoveries happened by chance (1928)**
  - cultures of staphylococci
  - Presence of fungus penicillium notatum
  - Inhibited the growth of bacteria
  - He named the substance Penicillin
  - But did not recognize its therapeutic potential.
- **In 1941 penicillin was used in humans**
  - E. Chain and H. Florey
  - They discovered Fleming's work
  - Tested penicillin for therapeutic purposes shortly before the outbreak of WW II
  - Numerous infectious and epidemic diseases
- **Fleming, Chain, and Florey: Nobel Prize in 1944**



# Antibiotic Resistance

- **20 to 50% of antibiotics are unnecessarily prescribed**
  - Cold, flu, bronchitis are diseases caused by viruses
  - Resolve without treatment in a few days
  - Prescribe under the pressure of time
    - Prescription → half a minute
    - Explain to the patient that the drug is not necessarily → 10 to 15 minutes
- **Resistance to antibiotics**
  - Microorganisms with resistance survive
  - Transmit their genetic material to other pathogens
  - Multidrug resistant pathogens

"My pediatrician is amazing. As soon as my daughter got a cold, he prescribed an antibiotic by phone and she recorved almost immediately”

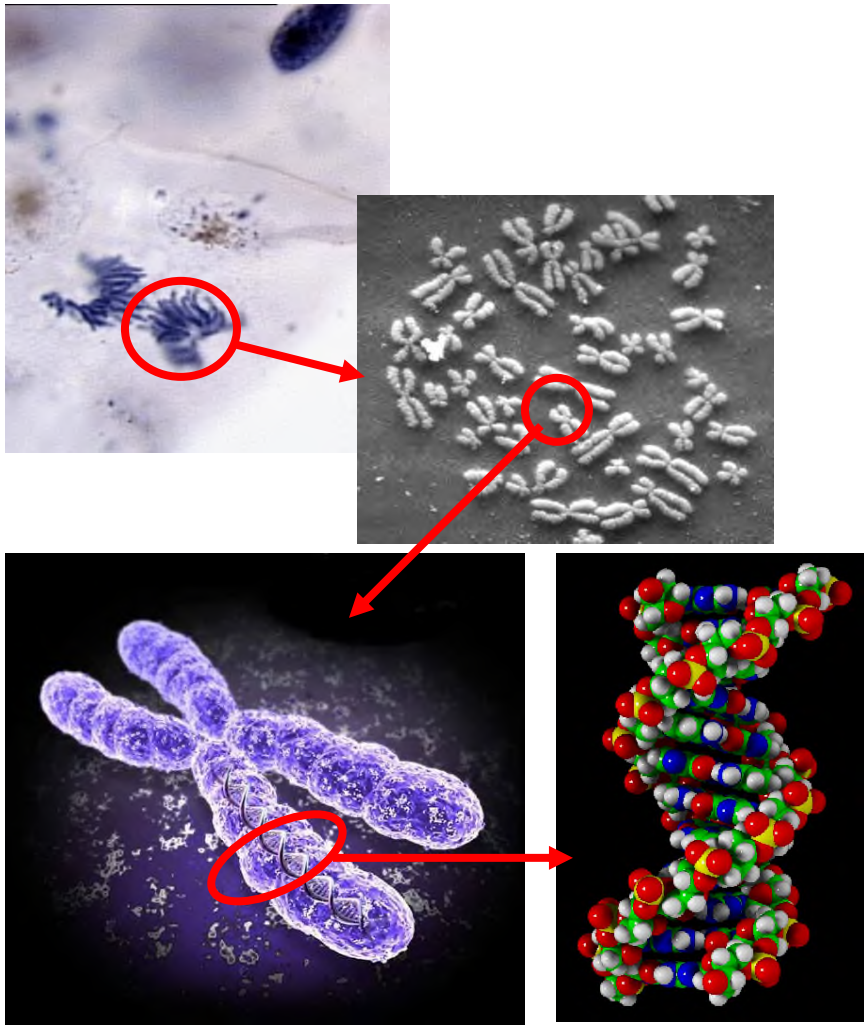
⇩

Uncontrolled outbreaks of bacterial diseases which can not be treated

# 1. Genetics / DNA

# Genetic Engineering

- **Deciphering the genetic code of the human**
- **Application to prevent or diagnose disease**
- **DNA**
  - In the cell nucleus in the form of chromosomes
  - Genes: a specific sequence of chemical structures
  - Contains the code for making proteins
  - The basis of the structure and function of each organism



# Genetic Engineering

- **Manufacturing of vaccines or hormones**
  - Treatment of specific diseases
  - Human insulin produced by transgenic bacteria (genetically engineered) for the treatment of diabetes
- **Mutant animals with distinct properties, eg**
  - Mutant cows that produce human milk
  - Pigs with organs that can be transplanted without complications in humans
- **Mutant plants with greater durability and productivity**

# Modern Technology

- **Major Developments**
  - pacemakers
  - defibrillators
  - ECG, EEG
  - artificial organs
  - transplants
  - laser
  - endoscopy
  - radiographs
  - magnetic resonance Imaging
  - computed tomography
  - ultrasound
  - nuclear medicine
  - artificial tissues
  - genetics
  - etc.

# Biomedical Engineering

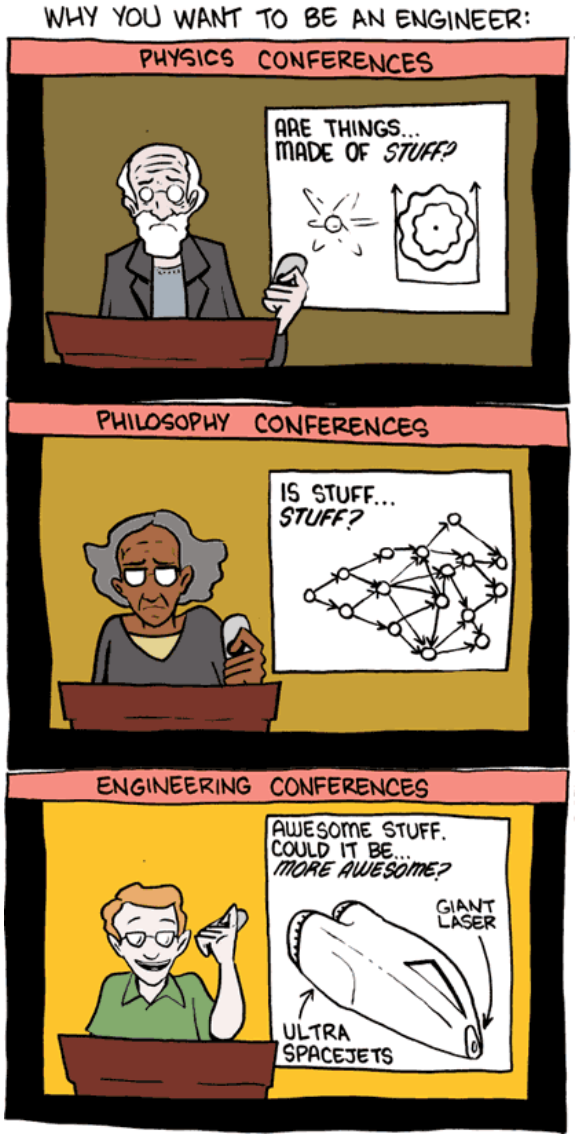
- **A loose definition of Biomedical Engineering:**
  - the application of engineering techniques and analyses to problem-solving in medicine and the biomedical sciences
- **Why Biomedical Engineering?**
  - Promising future developments
  - Improve medicine, save lives
  - Numerous possibilities based upon level of biology and engineering specialty
  - “Hybridization” of skills and knowledge

| Occupational Title | SOC Code | Employment, 2008 | Projected Employment, 2018 |
|---|---|---|---|
| Engineers | 17-2000 | 1,571,900 | 1,750,300 |
| Aerospace engineers | 17-2011 | 71,600 | 79,100 |
| Agricultural engineers | 17-2021 | 2,700 | 3,000 |
| Biomedical engineers | 17-2031 | 16,000 | 27,600 |
| Chemical engineers | 17-2041 | 31,700 | 31,000 |
| Civil engineers | 17-2051 | 278,400 | 345,900 |
| Computer hardware engineers | 17-2061 | 74,700 | 77,500 |
| Electrical and electronics engineers | 17-2070 | 301,500 | 304,600 |
| Electrical engineers | 17-2071 | 157,800 | 160,500 |
| Electronics engineers, except computer | 17-2072 | 143,700 | 144,100 |
| Environmental engineers | 17-2081 | 54,300 | 70,900 |
| Industrial engineers, including health and safety | 17-2110 | 240,400 | 273,700 |
| Health and safety engineers, except mining safety engineers and inspectors | 17-2111 | 25,700 | 28,300 |
| Industrial engineers | 17-2112 | 214,800 | 245,300 |
| Marine engineers and naval architects | 17-2121 | 8,500 | 9,000 |
| Materials engineers | 17-2131 | 24,400 | 26,600 |
| Mechanical engineers | 17-2141 | 238,700 | 253,100 |
| Mining and geological engineers, including mining safety engineers | 17-2151 | 7,100 | 8,200 |
| Nuclear engineers | 17-2161 | 16,900 | 18,800 |
| Petroleum engineers | 17-2171 | 21,900 | 25,900 |
| All other engineers | 17-2199 | 183,200 | 195,400 |

Bureau of Labor Statistics, U.S. Department of Labor, 2010

# Definitions

- **ENGINEERING vs. SCIENCE**
  - Scientist strive to create new knowledge about how things work.
  - Engineers understand well the tools science and mathematics provide, and utilize them to solve problems for public and economic gain.



# Definitions

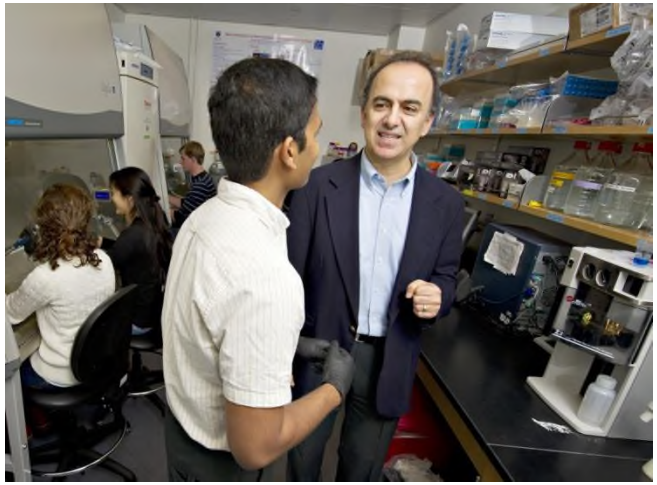
- **Biomedical engineering**
  - The use of engineering science and math to tackle problems in medicine. When distinguished from “bioengineering,” focuses more on the machine/device/non-biological type of research.
- **Bioengineering**
  - Often used interchangeably with “biomedical engineering”. When distinguishing between the two, typically bioengineering tends to refer to engineering using biological substances, often at a higher level of biology than biotechnology.
- **Biotechnology**
  - A term that is generally similar to “bioengineering,” but, in comparison, refers most specifically to direct manipulation and use of living biological substances
- **Clinical (medical) engineering**
  - The use of engineering, management concepts, and technology to improve health care and minimize cost in hospitals. Provide services directly dealing with problems originating in the clinical environment. Responsible for equipment effectiveness and safety and constrained by regulations.

# 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
- **to understand, modify, or control biologic systems**

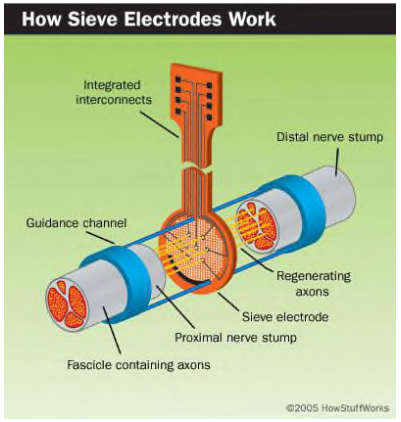
# Biomedical engineers

- **In its broadest sense, biomedical engineering involves training**
  - the clinical engineer in health care
  - the engineer for industry
    - biomedical design
    - technological entrepreneur
  - the research scientist

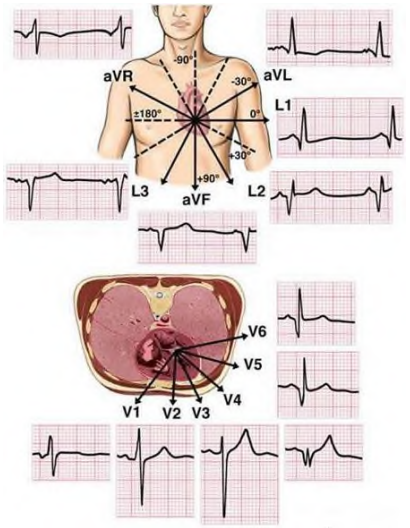


# Disciplines

- **Biomechatronics**
  - Aims to integrate mechanical, electrical, and biological parts together
  - e.g. sieve electrodes, advanced mechanical prosthetics
- **Bioinstrumentation**
  - Construction of devices for measuring aspects of physiological status
  - e.g. Electrocardiography (EKG), Electroencephalography (EEG),
- **Biomaterials**
  - Development of materials either derived from biological sources or synthetic, generally used for medical applications
  - e.g. Biopolymers, scaffold material for tissue engineering, coating for transplants
- **Biomechanics**
  - Study of mechanics as applied to biological structures
  - e.g. Musculoskeletal mechanics, trauma injury analysis



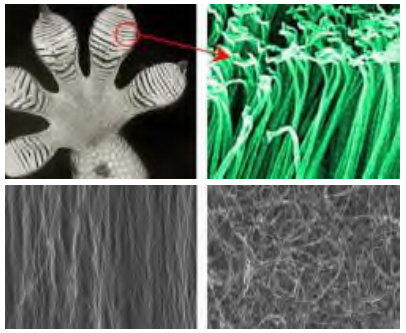
Sieve electrode design



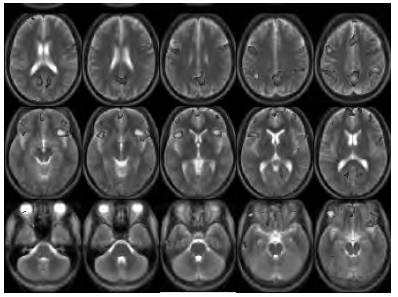
12 lead EKG configurations

# Disciplines

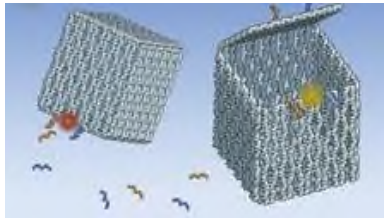
- **Bionics**
  - Also known as “biomimetics”, using biological mechanisms as an inspiration for engineered technology
  - e.g. gecko grip, velcro, architectural features
- **Cellular, tissue, genetic engineering**
  - Manipulation of living cells to replace/improve existing functions or to impart unique function
  - e.g. GMO crops, tissue regeneration
- **Medical imaging**
  - Visualization of anatomy and physiology, essential for modern diagnosis and treatment
  - e.g. X-ray, CAT, MRI, fMRI, PET, ultrasound
- **Bionanotechnology**
  - Combination of nanotechnology and biology
  - e.g. DNA nanotechnology and computing



Gecko foot and carbon nanotube imitation



Set of fMRI data



Boxes made with “DNA origami”

# Biomedical Engineering Minor