Ch1. Biomedical Engineering:
A Historical Perspective

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Evolution of the Modern Health Care System

-Primitive humans

considered diseases to be “visitations”.

-Primitive healers

- Evidence indicates that the primitive healer took an active rather than simply intuitive interest in the curative arts, acting as a surgeon, a user of tool
- -for example, making holes from skull to heal migraine headache or the epilepsy.

-Egypt

“Imhotep”(the architect of pyramid originally, god of healing later) for giving the sick peaceful sleep.

-Greece in 1000BC

- medicine was already a highly respected profession.
- temples may be considered among the first hospitals

-Hippocrates:

- [Hip kr tì z | -p k-] n. 히포크라테스(460?-377? B.C.) ((그리스의 의사; the Father of Medicine(의학의 아버지)이라고 불림))
- Born in Cos island, place for one of the healing temples(Aesculapia)
- the island of Cos, the birthplace of Hippocrates.
- Hippocrates viewed physician as scientist, taught disease was a natural process, one that developed in logical steps, and that symptoms were reactions of the body to disease.

-Hippocrates(cont'd)

- body itself possessed its own means of recovery , and the function of the physician was to aid these natural forces.His shrewd descriptions of diseases are models
- He and the school of Cos trained a number of individuals
- Romans to improve public health system

-Galen

- diagnosis became a fine art
- wrote more than 300 books of anatomical observations which included selected-human anatomy derived from animal dissections
- His words became "bible"and "the law" in the Dark Age.
- With the collapse of the Roman Empire, the church became the repository of knowledge.The employment of drugs signified lack of faith and scientific medicine fell into disrepute.

-The Renaissance and Reformation(15,16th centuries)

- the Church's stronghold on both the hospital and the conduct of medical practice was loosened (also time of Luther(1483-1546) ((독일의 신학자 종교 개혁의 지도자))
- ."True learning", the desire to pursue the true secrets anatomy was advanced-Michelangelo,Raphael Durer,Leonardo da vinci.
- Medical schools emerged.

-Quantification encouraged by Galileo

- Body temperature and pulse rate became measures
- Microscope amplified human vision.

-Henry VIII England patronized medicine.

-

Urban hospitals in England began practicing to help only curables.

-High death rate: In Hotel Dru in Paris (oldest hospital), death rate was 25% for patients, 6-12% for attendants.(1788)

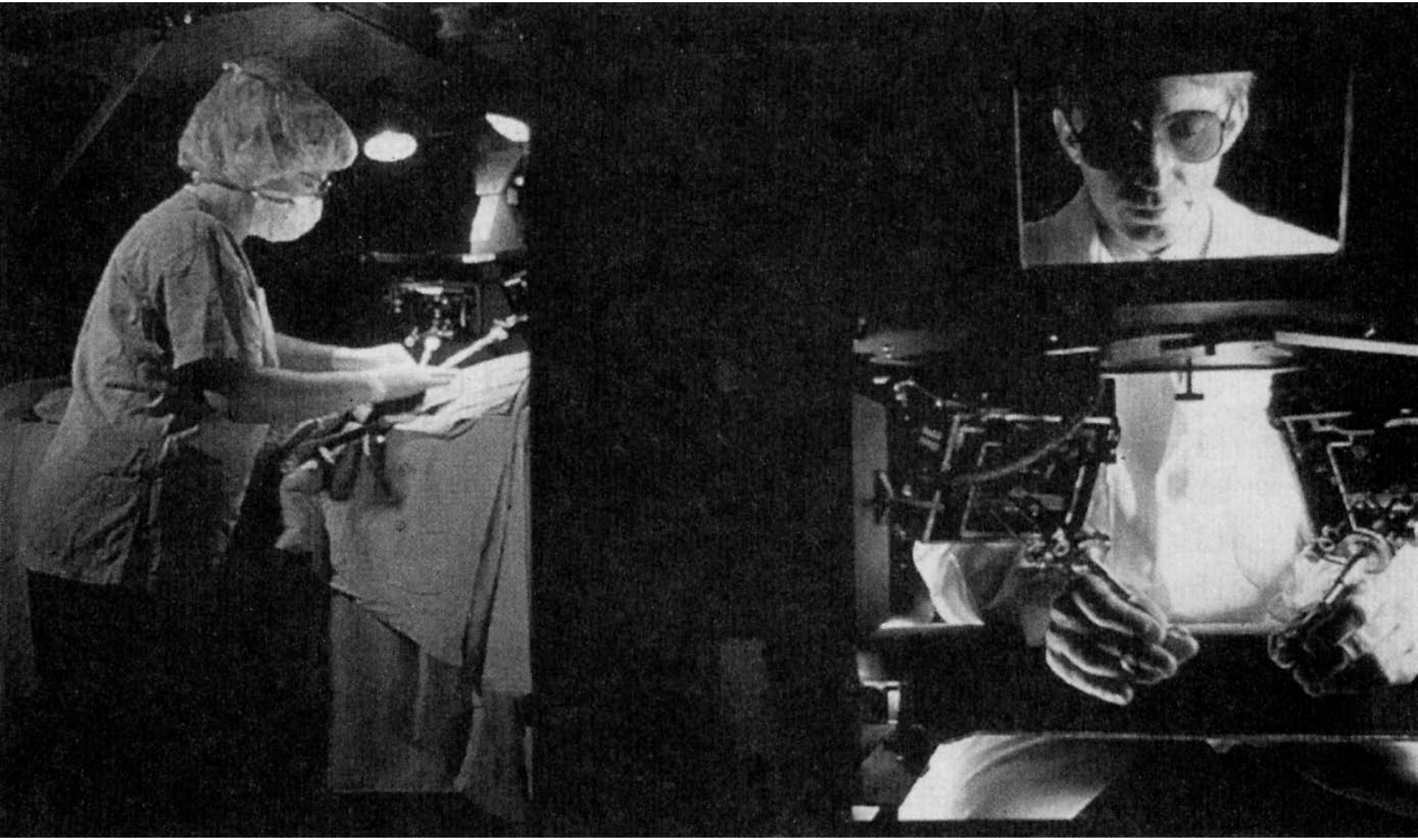
-Improved nursing by Florence Nightingale,"The art is that of nursing the sick, not sickness."

-Nevertheless, hospitals remained institutions for the sick(certain sickness) and poor.

-Institutions for the sick poor-for example,

1. In the 1870s, when the plans for the projected Johns Hopkins Hospital were reviewed, it was considered quite appropriate to allocate 324 charity and 24 pay beds.
2. In the 1873, approximately half of America's hospitals did not admit contagious diseases, and many other would not admit incurables.in this period, surgery admissions in general hospitals constituted only 5%, with trauma making up a good portion of these cases.

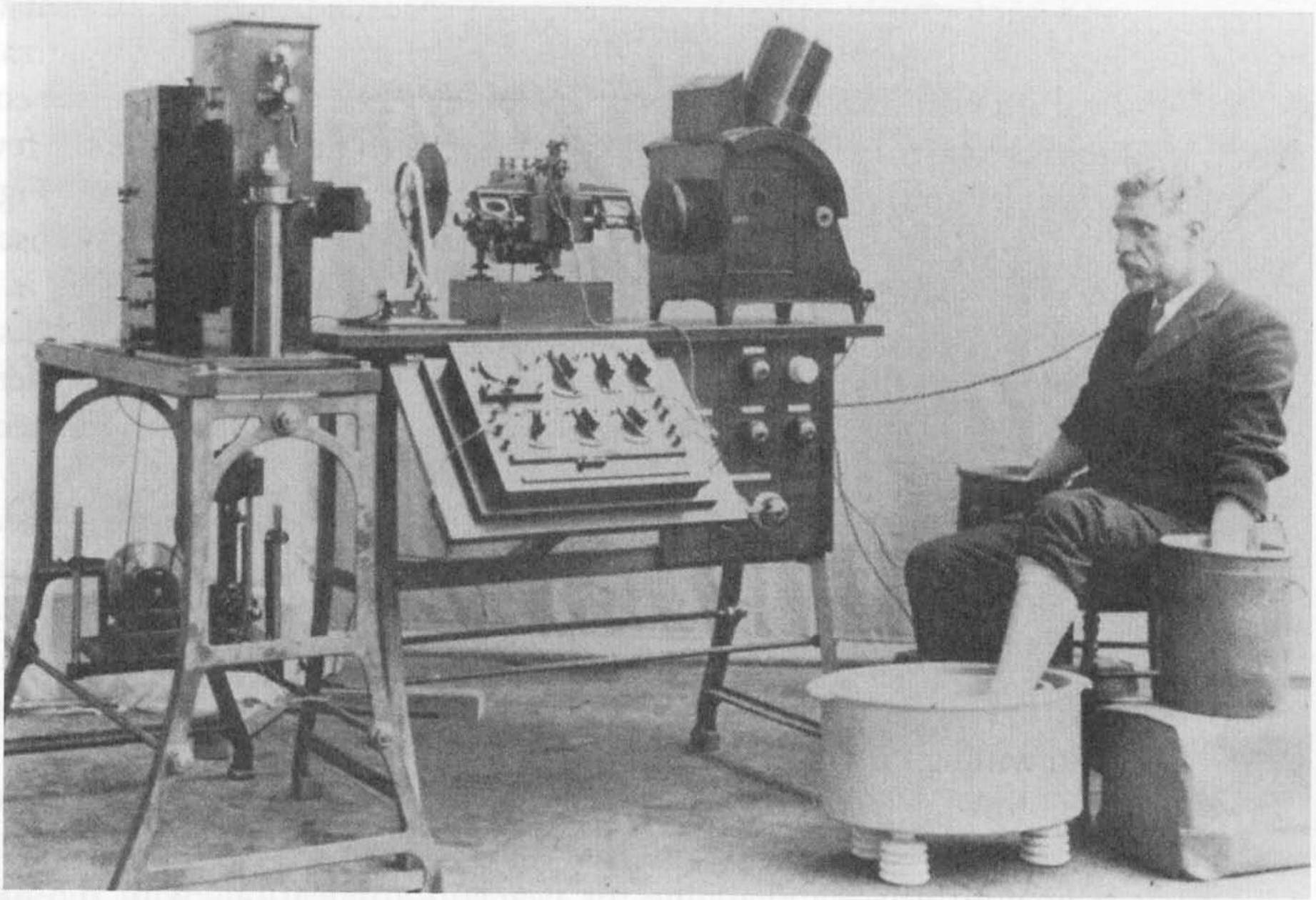
-Not until the twentieth century did "modern medicine" come of age.-technology played a significant role in its evolution.



(Technology brings)The Modern Health Care System

Discoveries in the physical sciences enabled medical researchers to take giant strides forward.

- The first electrocardiograph(Wiliam Einthoven,1903,Fig.1.1)—notice the three water basins acting as electrodes
- The development of X rays(W.K.Roentgen)
  - Beginning of medical imaging-paramount achievement
  - Barium salts and radiopaque materials
  - diagnose a wide variety of diseases and injuries accurately. Helped active curative hospital.



- Sulfanilamide(1930s),penicillin(early 1940s)
- sodium citrate(1913) and refrigeration (1930)to enable blood bank
- The Drinker respirator(1927),
- first heart-lung bypass(1939)
- Cardiac catheterization and angiography(1940s)
  - Cardiac and vascular surgery began
  - Angiography: the use of a cannula threaded thru an arm vein and into the heart wiith the injection of radiopaque dye for the x-ray visulization of lung and heart vessels and valves
- The electron microscope(1950s) for small cell visualization
- body scanner to detect tumors using radioactive materials (nuclear medicine)

- Following World War II, the evolution of comprehensive care greatly accelerated.
  - The technology developed in the pursuit of military objectives

    became available for peaceful application.
- What was considered science fiction in the past became reality. And most cases became outmoded in very short period of time.
- “Spare parts” surgery is now routine.
  - the first successful transplantation of a kidney (1954)
  - Artificial organs (figure 1.4)
- Imaging: CT and MRI
- The hospital has evolved by the change of modern life
  - the hospital specialized in highly technical and complex medical procedures.
  - Figure 1.2 surgical rooms (view robotic surgery)

INDUSTRIAL NEUROTECH

The neurostimulation market will reach US $3.8 billion by 2008, says publisher Neurotech Reports. Here are the companies to watch and what they sell.

1 MEDTRONIC INC.
Minneapolis, Minn.

Deep brain stimulators, spinal cord stimulators, sacral nerve stimulators

- Market leader in neurostimulation
- Activa deep brain stimulator recently approved for Parkinson's and other tremors
- Spinal cord stimulators treat chronic back pain
- Sacral nerve stimulators for urinary incontinence

2 COCHLEAR LTD.
Lane Cove, Australia

Cochlear implants, neural prostheses

- Market leader in cochlear implants
- Its Nucleus Pty. group is developing a standing/walking prosthesis for the paralyzed

3 SYNAPSE BIOMEDICAL LTD.
Olentin, Ohio

Diaphragm pacing system

- Phrenic nerve stimulator for pacing breathing eliminates need for mechanical ventilator in severely paralyzed

4 ADVANCED BIONICS INC.
Sylmar, Calif.

Cochlear implants

- Among top three in cochlear implants
- Hopes to sell injectable Bion stimulators for urinary incontinence within a year
- Coming: spinal cord and deep brain stimulators to compete with Medtronic

5 ADVANCED NEUROMODULATION SYSTEMS INC.
Plano, Texas

Spinal cord stimulators

- No. 2 in neurostimulation
- Genesis spinal cord stimulator has cut into Medtronic's market
- Coming: deep brain stimulator

6 NORTHSTAR NEUROSCIENCE
Seattle, Wash.

Stimulators for stroke rehabilitation

- Developing brain stimulator to help stroke patients recover movement
- Developed, then sold off a stimulator for treating back pain using through-the-skin electrodes
- Received $37 million in venture capital in 2002

7 CYBERKINETICS INC.
Foxborough, Mass.

Brain-computer interfaces, mini-readout readers

- Start-up is developing BrainGate brain-computer interface to interpret signals from brain, so paralyzed patients can control neural prosthesis or external device
- Recently merged with Bionic Technologies, maker of an implantable microelectrode array

8 CYBERONICS INC.
Houston, Texas

Vagus nerve stimulators

- Device implanted in chest wall activates vagus nerve leading to brain that is thought to pace physiological functions like respiration and heartbeat
- Stimulator has been shown to suppress epileptic seizures, and is being evaluated for treating depression and obesity

9 AFFERENT CORP.
Providence, R.I.

Sensory stimulators

- Device for restoring sense of touch and balance lost because of stroke, diabetes, or other disorders

10 ROBOMEDICA INC.
Culver City, Calif.

Step training

- Systems to teach people with neurological disorders and other impairments to walk

P32,IEEE Spectrum, April 2004

What is Biomedical Engineering?

- **Biomedical engineer is who challenges many problem in the modern heath care system.**
- **Can mean a few things.**
  - **Reference 1990, Pacela, Bioengineering Education Directory.**

- **When Bioengineering means to describe a basic research oriented activity closely related to biotechnology and genetic engineering, typical pursuits of biomedical engineers include**
  - Development of improved species of plants and animals for good production
  - Invention of new medical diagnostic tests for diseases
  - Productinof synthetic vaccines from clone cells
  - Bioenvironmental engineering to protect human, animal, and plant life from toxicant and pollutants
  - Study of protein-surface interactions
  - Modeling of the growth kinetics of yeast and hybridoma cells
  - Research in immobilized enzyeme technology
  - Development of therapeutic proteins and monoclonal antibodies

BioMEDical engineering has more comprehensive meaning. Biomedical engineer involves applying the concepts,

- **knowledge, and approaches of virtually all engineering disciplines(e.g., electrical, mechanical, and chemical engineering) to solve specific health care-related problems, the opportunities for interaction between engineers and health care professionals are many and varied.**
- **The field has moved significantly from being concerned primarily with the development of medical devices in the 1950s and 1960s to include a more wide-ranging set of activities.(Fig. 1.7)**

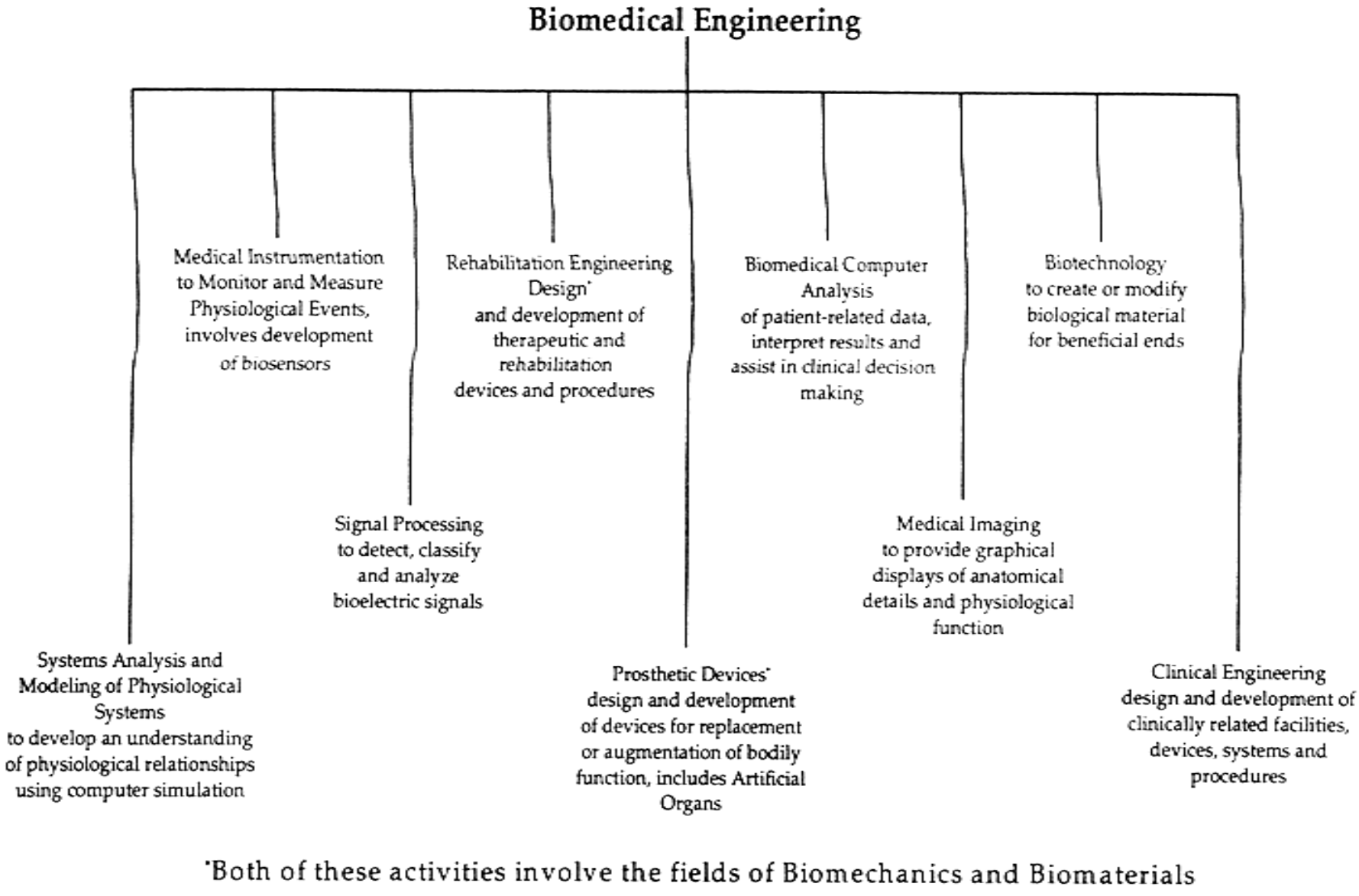


Fig.1.7 Schematic diagram illustrating the various fields of activity within the discipline of biomedical engineering

- **Biomedical Engineering(Cont'd)**
- **These areas include**
  - Application of engineering system analysis(physiologic modeling, simulation, and control to biological problems)
  - Detection, measurement, and monitoring of physiologic signals (i.e., biosensors and 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(I.e., medical informatics and artificial intelligence)
  - Medical imaging, that is, the graphical display of anatomic detail or physiologic function
  - The creation of new biologic products(I.e., biotechnology and tissue engineering)

- **Typical pursuits of biomedical engineers include**
  - Research in new materials and devices for implanted artificial organs
  - Development of new diagnostic instruments for blood analysis
  - Computer modeling of the function of the human heart
  - Writing software for analysis of medical research data
  - Analysis of medical device hazards for safety and efficacy
  - Development of new diagnostic imaging system
  - Design of telemetry system for patient monitoring
  - Design of biomedical sensors for measurements of human physiologic system variables
  - Development of expert systems for diagnosis of diseases
  - Design of closed-loop control systems for drug administration
  - Modeling of the physiologic systems of the human body
  - Design of instrumentation for sports medicine
  - Development of new dental materials
  - Designs of communication aids for the disabled
  - Study of pulmonary fluid dynamics
  - Study of biomechanics of the human body
  - Development of material to be used as replacement for human skin

Roles played by Biomedical Engineers

Biomedical engineering involves training three types of individuals:

(i) the clinical engineer in health care

(ii) the biomedical design engineer for industry

(iii) the research scientist

Currently one might also distinguish among three specific roles these biomedical engineers can play.

(i) problem solver

(ii) technological entrepreneur

(iii) engineer scientist

- **Problem solver**
  - most likely the clinical engineer or biomedical design engineer
  - maintains the traditional service relationship with the life scientist
  - must understand the biological situation to apply their judgment and contribute their knowledge toward the solution as well as to explain their methods in terms that the life scientist can understand
  - Example: clinical engineering in a hospital

- **Technological entrepreneur**
  - most likely a biomedical design engineer in industry
  - examine some portion of the biological or medical front and identify areas in which advanced technology might be advantageous
  - pose their problem and then proceed to provide the solution , at first conceptually and then in the form of hardware or software.Finally, they convince the medical community that they can provide useful tool
  - Because of the nature of their work, technological entrepreneurs should have a great deal of engineering and medical knowledge as well as experience in numerous medical system.

-example: an engineer working in biochip industry, a founder of a company

- **engineer scientist**
  - Most likely found in academic institutions and industrial research labs
  - Interested in applying engineering concepts and techniques to the investigation and exploration of biological processes
  - Use appropriate physical or mathematical model

    the mathematical description forms a compact,precise language that is easily communicated to others
  - The activities of the engineer scientist involve instrument and device development
  - Example, an electrical engineer developing electrodes for cochlear implant, a chemical engineer working in gene therapy (fig 1.10) (understand this figure)

- **“The Ultimate role of the biomedical engineer, like that of the nurse and physician, is to serve society.”** This is a profession, not just a skilled technical service.

Professional Status of Biomedical Engineering

"Biomedical engineers are professionals."

-Professionals have been defined as an aggregate of people finding identity in sharing values and skills absorbed during a common course of intensive training.

- The definition of professional
  - Passons(1950) : One determines whether individuals are professionals by examining whether or not they have internalized certain given professional values.
  - Friedson(1971,redefined Parson's definition):

    A professional is someone who has internalized professional values and is to be recruited and licensed on the basis of his or her technical competence. professionals generally accept scientific standards in their work, restrict their work activities to areas In which they are technically competent, avoid emotional involvement, cultivate objectivity in their work, and put their clients' interests before their own.

- **Science vs. Profession**
  - Science is seen as the pursuit of knowledge, its value hinging on providing evidence and communicating with colleagues.
  - Profession is viewed as providing a service to clients who have problems they cannot handle themselves.
  - Scientists practice their skills and report their results to knowledgeable colleagues.
  - Professionals serve lay clients.
  - Professionals endorse and follow a specific code of ethics to serve society.
  - Scientist move their colleagues to accept their findings through persuasion.
- **A final attribute of professionals is that of integrity(a person with internal ethical,moral values who is viewed dependable by others). (example. Physician dealing with a terminally ill patient with pain.)**

- **Professional societies play a major role in bringing together members of this diverse community to share their knowledge and experience in pursuit of new technological applications that will improve the health and quality of life of human beings.**
  - 의용생체공학회
  - 전자공학회
  - 센서학회
  - Institute of Electrical and Electronic Engineers(IEEE) Engineering in Medicine and Biology Society (EMBS)
  - International Federation of Medical and Biological Engineers(IFMBE)
  - American Institute of Medical and Biological Engineers(AIMBE)

1.6 Professional Societies

--International Federation for Medical and Biological Engineering

- Established in 1959
- Organization made up from an affiliation of national societies including members of transnational organizations
  -currently, the federation has an estimated 25,000 members from all of its constituent societies.
- The primary goal: to recognize the interests and initiatives of its affiliated member organizations and to provide an international forum for the exchange of ideas and dissemination of information.
- Publication:
  - the journal of Medical and Biological Engineeering and Computing (bimonthly journal)
  - The MBEC news
  - http://vub.vub.ac.be/~ifmbe/ifmbe.html

-IEEE Engineering in Medicine and Biology society

- The IEEE is the largest international professional organization in the world and accommodates 37 different societies and councils under its umbrella structure.
- The EMBS represents the foremost international organization serving the need of more than 8000 biomedical engineering members around the world.

-- publications:

- ***Transaction on Biomedical Engineering*(TBME: a monthly journal)**
- ***Transaction on Rehabilitation Engineering***
- ***Transaction of Information Technology in Biomedicine*(two quarterly journals))**
- ***IEEE Engineering in Medicine and Biology magazine*(a bimonthly magazine)**

-- http://ww.ieee.org/embs/

- **American Institute for Medical and Biological Engineering(AIMBE)**
  - **Created in 1992**
  - **Primary goal: to serve as an umbrella organization in the United States for the purpose of unifying the bioengineering community, addressing public policy issues, and promoting the engineering approach in society's effort to enhance health and quality of life through the judicious use of technology.**

- http://bme.www.ecn.purdue.edu/BME/societies/AIMBE/aimbe.html

Other journals:

- **Science**
- **Nature**
- **Biomedical Instrumentation and Technology**
- **Annals of Biomedical Engineering**
- **Journal of Clinical Engineering**
- **Journal of Neuroscience Methods**
- **Journal Of Neural Engineering**
- **Computer Methods andPrograms in Biomedicine**
- **Neural Computation**
- **Many others**