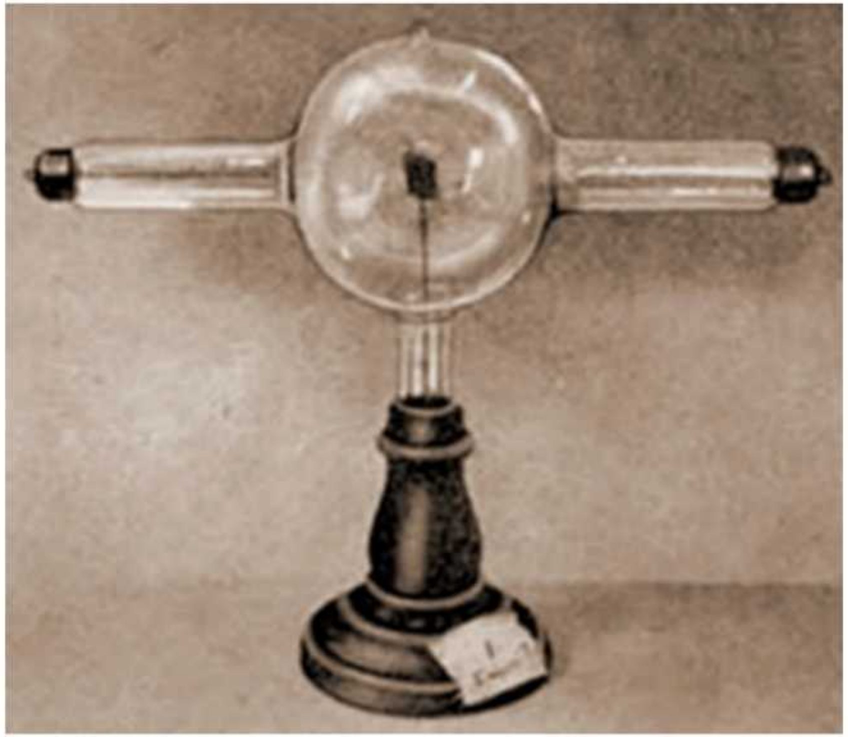
The history of medical equipment innovation

- Discovery of X-ray (late 1800s)
- First electro-cardiogram recording (early 1900s)
- Electronic amplification (1940s)
- Medical innovation based on military innovation (1950s)
- Pacemaker (1960s)
- Electrical safety (1970s)
- Increasingly high-tech healthcare (1980s)
- Current innovations (molecular diagnostics)



13.2.1 Outline the history of medical equipment innovation

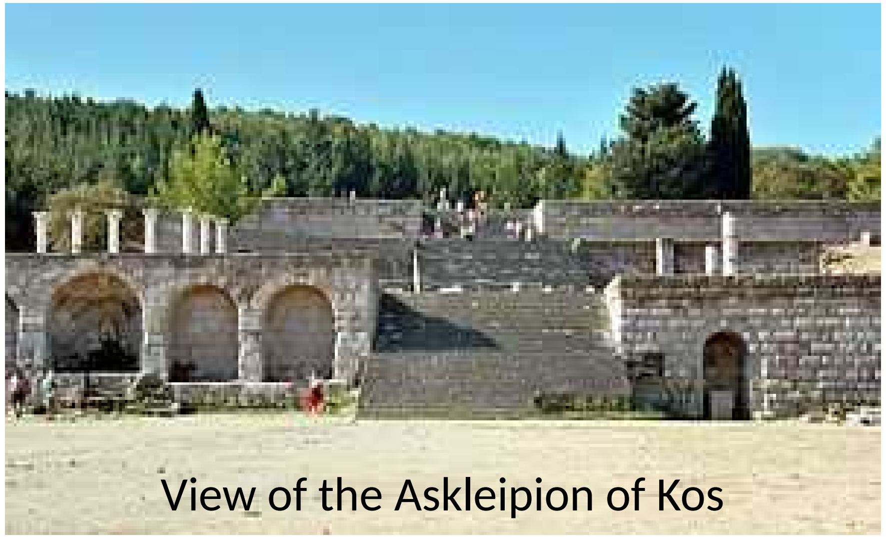
Unit B 13.2 Medical Equipment Uses and Categories

Module 279 18 B Medical Instrumentation I

highlights of Hippocrates Oath: the power of the Physician !

I swear by Apollo the physician, and Aesculapius the surgeon, likewise Hygeia and Panacea, and call all the gods and goddesses to witness, that I will observe and keep this underwritten oath…

… Nor shall any man's entreaty prevail upon me to administer **poison** to anyone; neither will I counsel any man to do so. Moreover, I will give no sort of medicine to any pregnant woman, with a view **to destroy the child.**


View of the Askleipion of Kos

Whatsoever house I may enter, my visit shall be for the convenience and advantage of the patient; and **I will willingly refrain from doing any injury** or wrong from falsehood, and **from acts of an amorous nature**, whatever may be the rank of those who it may be my duty to cure, whether mistress or servant, bond or free.

Whatever, in the course of my practice, I may see or hear (even when not invited), whatever I may happen to obtain **knowledge** of, if it be not proper to repeat it, **I will keep sacred and secret** within my own breast.

If I faithfully observe this oath, may I thrive and prosper in my fortune and profession, and live in the estimation of posterity; or on breach thereof, may the reverse be my fate!

Treatment of Disease before 1900

Historic focus of disease treatment:

- health products found in nature
- locally accumulated ‘home remedies’
- surgery / dentistry
- care for the dying and the insane

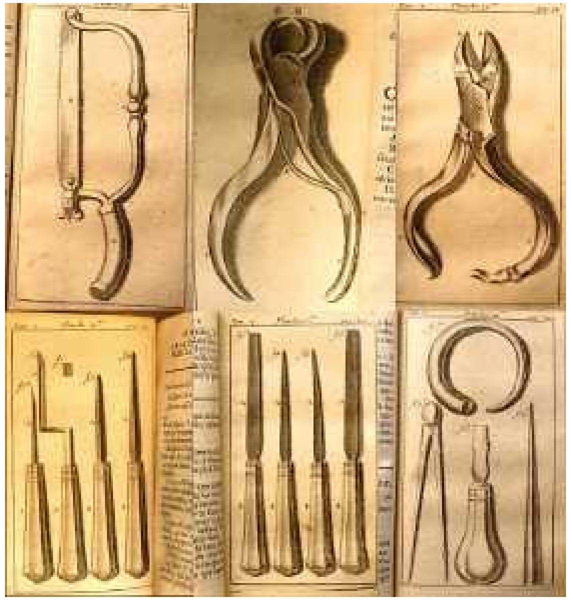
“… and those illnesses not cured by home remedies were left to run their natural, albeit frequently fatal, course.”

Traditional Medicine on a market in Madagascar

… with very little ‘medical equipment’

Early Surgery and Dentistry

Brain surgery in pharaonic Egypt



surgical tools

Medieval Islamic dentistry

In the European Middle Ages dentistry and surgery was performed by barbers

Hospices and Asylums

Hospices were places to care for the terminally ill, the incurable disease and the dying.

Lunatic asylums were places to care for the mentally ill

in case the personal environment of the patient could not carry the burden.

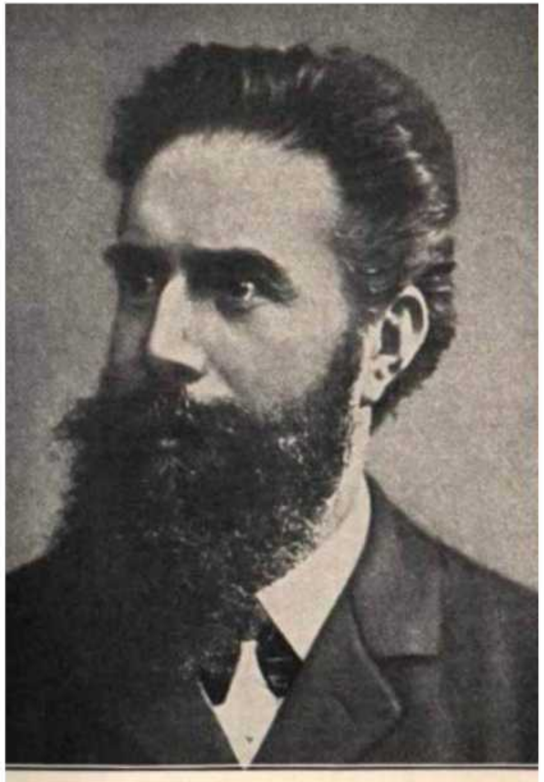
often run by people with religious motives (monks, nuns)

19th Century inventions

The **19th century** was an era of rapidly accelerating scientific discovery and invention, with significant developments in the fields of **mathematics, physics, chemistry, biology, electricity, and metallurgy** that laid the groundwork for the technological advances of the 20th century

1800 - Volta: invents the battery
1827 - Ohm: Ohm's law (Electricity)
1827 - Avogadro: Avogadro's law (Gas law)
1831 - Faraday discovers **electromagnetic induction**
1838 - Schleiden: all plants are made of cells
1843 - Joule: Law of Conservation of energy
1846 - Morton: discovery of anesthesia
1848 - Kelvin: absolute zero
1858 - Virchow: cells can only arise from pre-existing cells
1859 - Darwin: Theory of evolution by natural selection
1861 - Pasteur: Germ theory
1865 - Mendel: Mendel's laws of inheritance, basis for genetics
1873 - Maxwell: Theory of electromagnetism
1875 - Crookes invented the Crookes tube and cathode rays
1895 - Röntgen discovers x-rays
1896 - Becquerel discovers **radioactivity**
1897 - Thomson discovers the electron in cathode rays
1898 - Curie discovers polonium, radium, and "**radioactivity**"

Discovery of X-ray for medical imaging: W.K. Röntgen, 1895



WILHELM KONRAD ROENTGEN (1845–1923)
Discoverer of X-rays, the foundation of Electron Physics

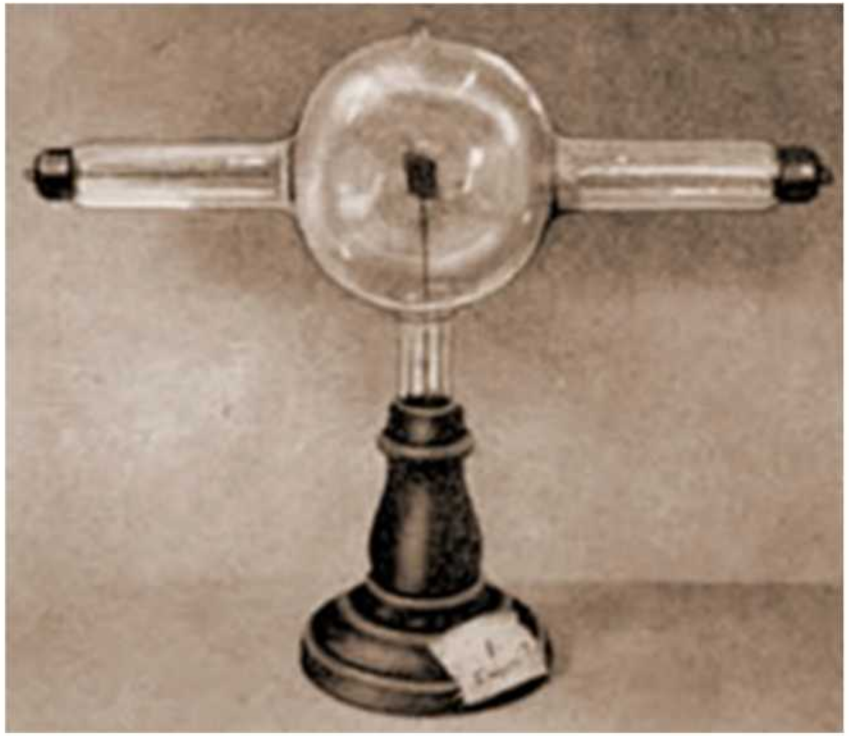
"Röntgen was investigating cathode rays using a fluorescent screen painted with barium platinocyanide and a Crookes tube which he had wrapped in black cardboard so the visible light from the tube would not interfere. He noticed a faint green glow from the screen, about 1 meter away. Röntgen realized some invisible rays coming from the tube were passing through the cardboard to make the screen glow. He found they could also pass through books and papers on his desk. Röntgen threw himself into investigating these unknown rays systematically. Two months after his initial discovery, he published his paper.

Röntgen referred to the radiation as "X", to indicate that it was an unknown type of radiation.

Rontgen's first "medical" X-ray, of his wife's hand

The gentleman, private, investigator and his 'accidental' discovery

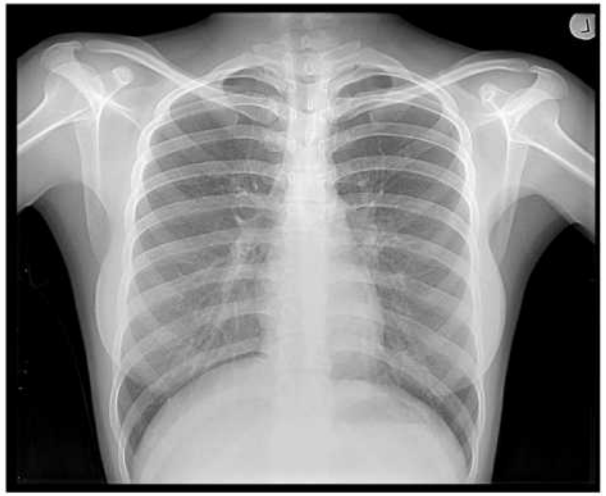
Discovery of X-ray for medical imaging: W.K. Röntgen, 1895



X-ray technology triggered the transformation of the hospital from a passive receptacle for the sick to an active curative institution for all members of society. **It was the start of the department of Radiology**.

During this same time, hospitals turned from private into public institutions.

By the 1930's x-ray visualization of practically all organ systems of the body had been made possible through the use of barium salts and a wide variety of radiopaque materials …

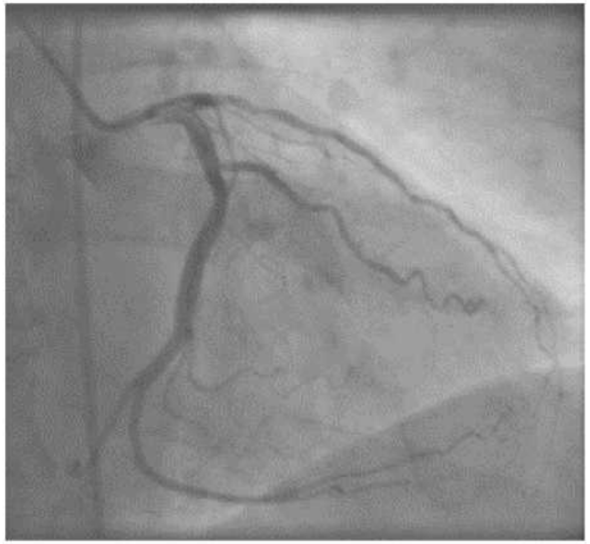


chest

foot and hand

neck and skull

hips



© contrast filled blood vessels in the brain and heart,

aorta and kidneys

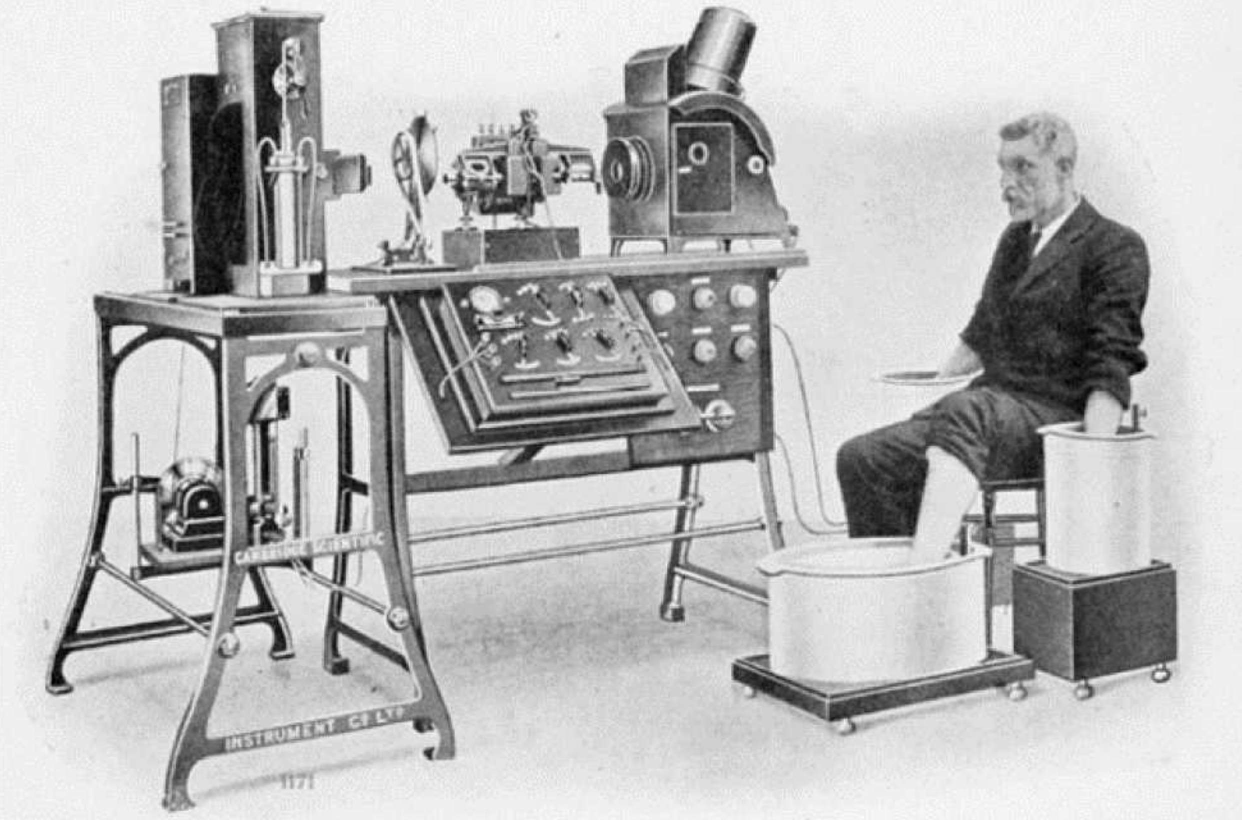
contrast in intestines

First electro-cardiogram recording (early 1900s)


1903 - Willem Einthoven discovers electrocardiography (ECG/EKG)

Willem Einthoven (1860 – 1927) was a Dutch doctor and physiologist.
He received the Nobel Prize in Medicine for his discovery in 1924.

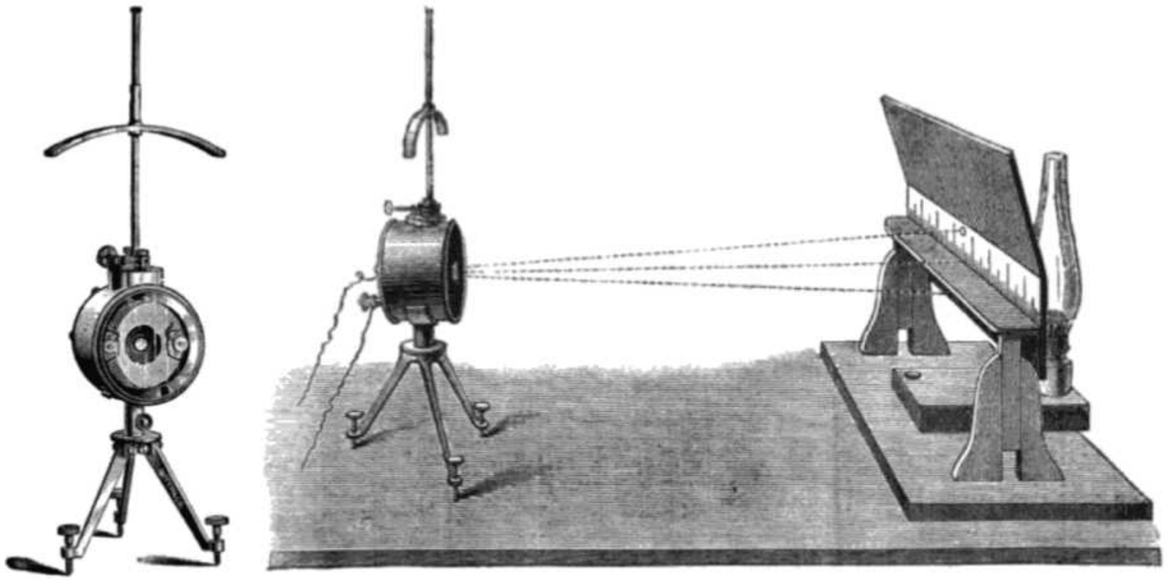
early commercial ECG machine



PHOTOGRAPH OF A COMPLETE ELECTROCARDIOGRAPH, SHOWING THE MANNER IN WHICH THE ELECTRODES ARE ATTACHED TO THE PATIENT, IN THIS CASE THE HANDS AND ONE FOOT BEING IMMERSED IN JARS OF SALT SOLUTION

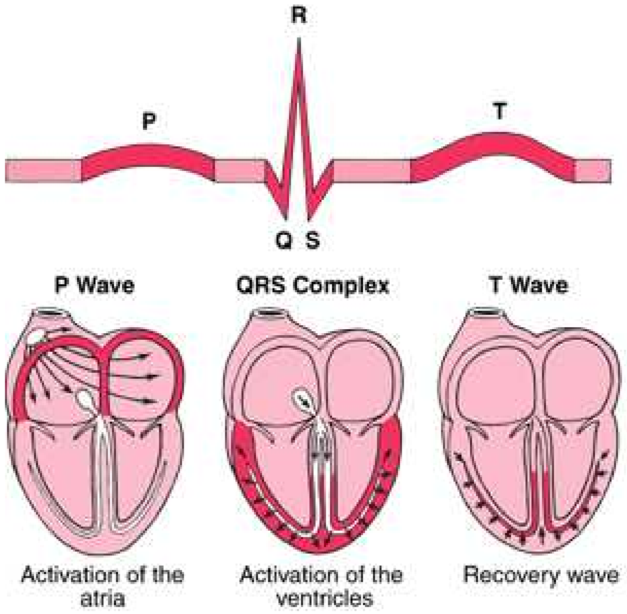
First electro-cardiogram recording

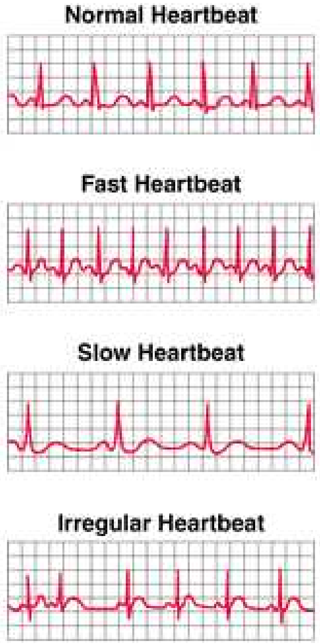
The string galvanometer, invented by Einthoven, was one of the earliest instruments capable of detecting and recording the very small electric currents produced by the human heart and produced the first reliable electrocardiograms.

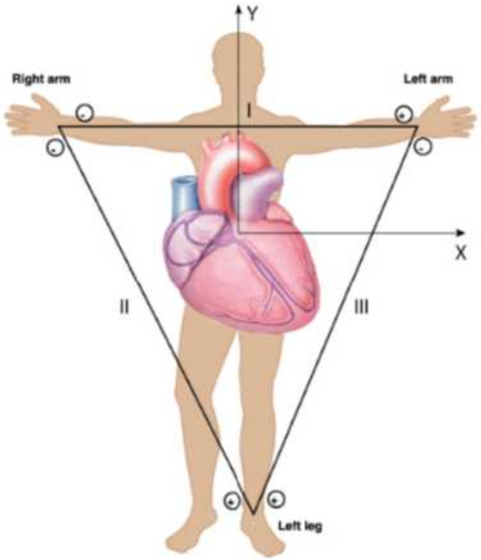


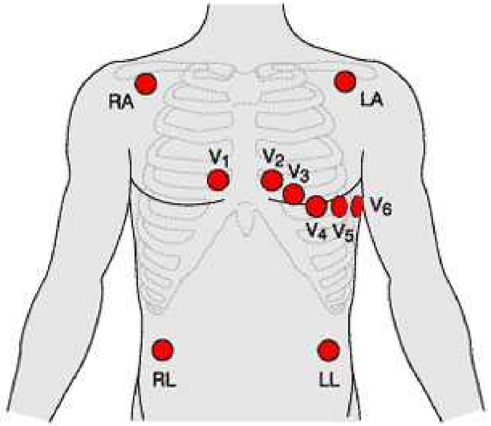
Einthoven's invention consisted of a long silver-coated quartz wire that conducted the electrical currents from the heart. This wire was acted upon by powerful electromagnets positioned either side of it, which caused sideways displacement of the filament in proportion to the current carried due to the electromagnetic field. The movement in the filament was heavily magnified and projected onto a moving photographic plate.

Electro-cardiogram recording









each ECG component can be associated
with certain electrical activities in the heart
(P,Q,R,S,T are still used definitions from Einthoven !)

different placements of ECG electrodes
emphasize different electro-cardiac
phenomena (‘viewing angle’)

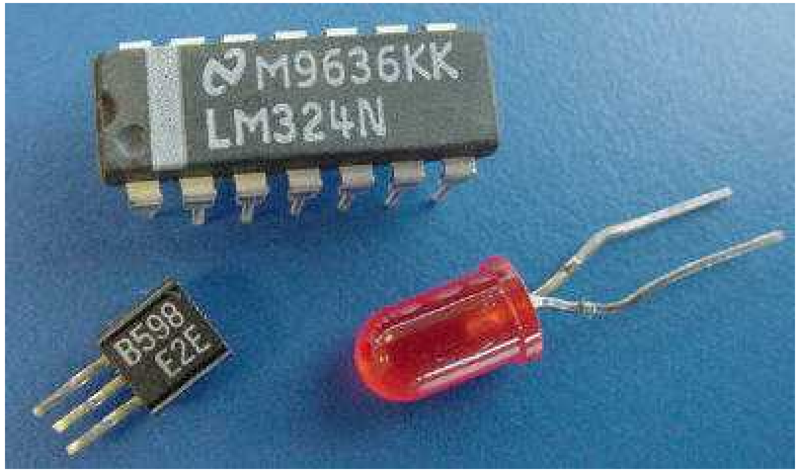
Electronic amplification (1940s)

Start of many Medical Electronics applications from technology developed in university R&D labs such as solid state electronics (transistor, 1947) and advances in materials knowledge

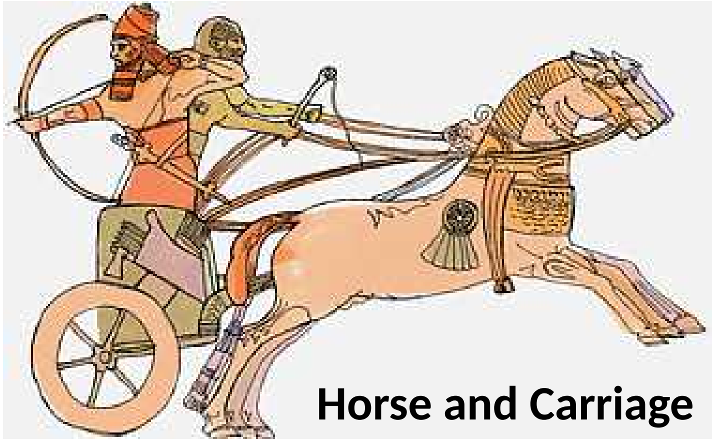
- vector electro-cardiography
- bioelectric signals EEG, EMG
- cardiac pacemaker
- intracellular activity measurement

Building of many hospitals in (‘Western’) societies that became rapidly richer.

Start of Medical Physics departments in hospitals



Military innovation has often decided history



Horse and Carriage

Greek Phalanx

Greek fire

Longbow man vs classic archer

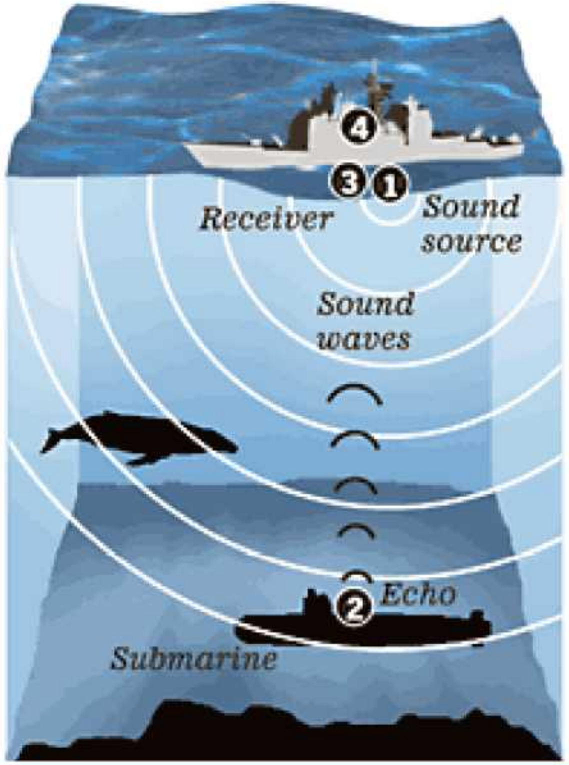
Gatlin Gun

Nuclear Bomb

Military Innovation

The military funding of science has had a powerful transformative effect on the practice and products of scientific research since the early 20th century. Particularly since World War I, advanced science-based technologies have been viewed as essential elements of a successful military.

World War I is often called "the chemists' war", both for the extensive use of poison gas and the importance of nitrates and advanced high explosives. Poison gas was used extensively by the Germans and the British; over the course of the war, scientists on both sides raced to develop more and more potent chemicals and devise countermeasures against the newest enemy gases.



Physicists also contributed to the war effort, developing wireless communication technologies and sound-based methods of detecting U-boats, resulting in the first long-term connections between academic science and the military.

Military Innovation

Computer science and computer engineering were shaped, in the first decades of digital computing, almost entirely by military funding.

Most of the basic component technologies for digital computing were developed through the course of a program to develop an automated radar shield.

Virtually unlimited funds enabled two decades of research that only began producing useful technologies by the end of the 50s. More so than with previously-established disciplines receiving military funding, the culture of computer science was permeated with a Cold War (Soviet Union & the West) military perspective.

Examples of military inventions leading to Medical equipment:

- Nuclear Medicine (atomic age !)
- submarine sonar counter measures >> ultrasound applications
- artificial heart valves (durable materials)
- image intensifiers (originally for night viewing)

A history of military contributions

By Teresa Bitler

Wounded warriors in Iraq and Afghanistan have a 95 percent chance of surviving their battlefield injuries—the highest survival rate in the history of warfare—if they receive immediate care and are transported to an advanced-level treatment facility within the "golden hour," the initial 60 minutes following trauma.

These combat-tested medical innovations have upped the troop survival rate over the last century and have saved lives on the home front, as well.

WORLD WAR I

(1914-1918)

Triage

The French introduced the concept of triage—prioritizing the wounded in an attempt to maximize survivors—to the battlefields of World War I, where United States soldiers quickly adopted the practice. After the Korean and Vietnam wars, U.S. forces became so proficient in its application that triage became standard practice in U.S. hospital emergency room care.

WORLD WAR II

(1939-1945)

Penicillin

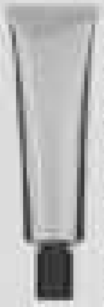
Although Sir Alexander Fleming discovered penicillin in 1928, it wasn't manufactured until World War II, when the need for a wartime antibacterial agent was great. Using a unique fermentation process, American companies began mass-producing penicillin for the battlefield. Penicillin entered the combat arena in the spring of 1943, and achieved incredible success in treating infections for the remainder of the war and thereafter.

Blood banking

With the German invasion of Great Britain seemingly imminent in 1940, the U.S. stepped up to perfect the seperation of blood into plasma, as well as its transport from blood collection centers to battlefields and hospitals. Dr. Charles Drew implemented a blood-banking process that helped save lives on World War II battlefields, and laid the foundation for a modern day blood-banking system.

VIETNAM WAR

(1954-1975)

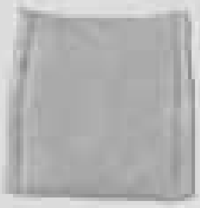


Wound adhesives

The super-sticky compound cyanoacrylate debuted in spray form during the Vietnam War, when medics used it to seal wounds long enough for soldiers to reach a treatment facility. However, the substance caused skin irritations, so researchers discovered another variation, 2-octyl-cyanoacrylate, which formed stronger bonds with fewer side effects. In 1998, the U.S. Food and Drug Administration approved its medical use and today it is used worldwide.

OPERATION DESERT STORM

(1991)



Hemostatic bandages

Since approximately 50 percent of those who die in combat bleed to death in minutes, blood-clotting bandages can literally mean the difference between life and death. QuickClot, a product that uses the mineral kaolin, led the way in the early days of Operation Desert Storm. As the war progressed, hemostatic bandages became a military staple and in 2006, the U.S. Army Surgeon General mandated that all soldiers serving in Iraq or Afghanistan carry at least one hemostatic bandage.

IRAQ AND AFGHANISTAN

(2002-Present)

One-handed tourniquet

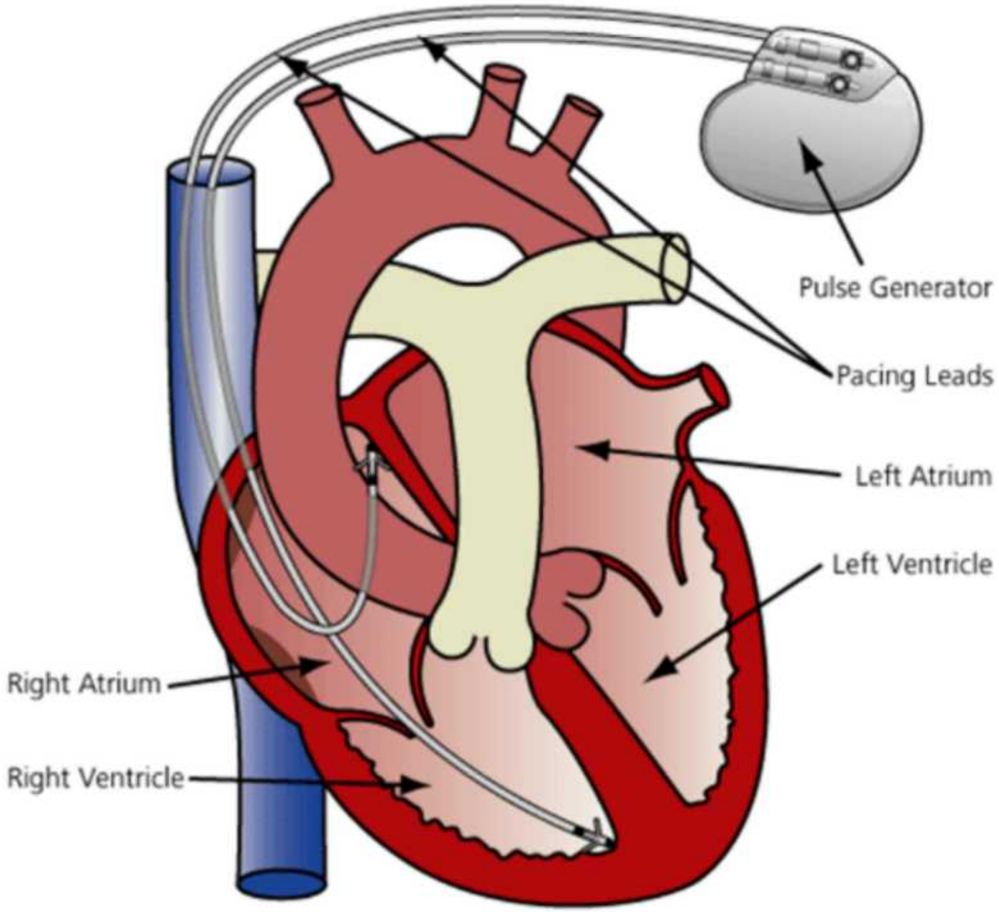
Tourniquets date back to the Romans, but to successfully apply one on the upper extremities, you need two hands. Advances in tourniquet technology have changed that, though. The Combat-Application-Tourniquet, or C-A-T, can be applied with one hand. The device consists of a band that slips onto the extremity and a windlass rod that easily twists to constrict blood flow to the limb. In addition to hemostatic bandages, the one-handed tourniquet is now standard issue in soldiers' first aid kits, and it has made its way into mainstream medicine, where EMTs, police and other first responders use it.

Pacemaker (1960s): an example of rapid expansion

An (artificial) pacemaker is a medical device which uses electrical impulses, delivered by electrodes contracting the heart muscles, to regulate the beating of the heart.

The primary purpose of a pacemaker is to maintain an adequate heart rate, either because the heart's natural pacemaker is not fast enough, or because there is a block in the heart's electrical conduction system. Modern pacemakers are externally programmable and allow a cardiologist to select the optimum pacing modes for individual patients.

Some pace makers have multiple electrodes stimulating different positions within the heart to improve synchronisation of the chambers (ventricles) of the heart.



Pacemaker (1960s)

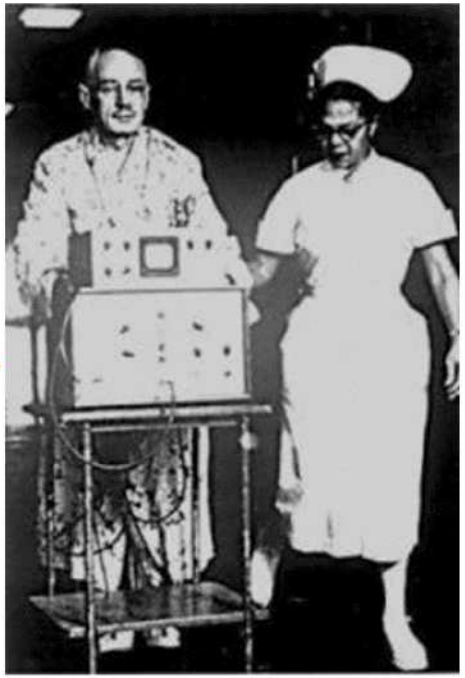
A pacemaker generator is a complex electronic instrument that consists of 3 essential components:

- the metal encasement of the electronic circuit,
- the electronic circuit
- the battery

The generator is then attached to pacing leads which conduct electrical impulse to the myocardium.

The size of early pacemakers was about the size of a man's wristwatch. It is made up of titanium and contains a lithium battery along with the electronic circuitry that controls the pacing system. The lifespan of the battery usually varies from 8 to 10 years.

The development of the silicon transistor (1956) led to rapid development of practical cardiac pace-making



Mid 1950s - Heart paced through an **external** pulse generator and internal leads
1958 - Implantable pacemakers
1970s - Lithium batteries (life time 8 years), programmability and integrated circuits
1980s - Dual Chamber Pacing
1990s - Volume growth through wider clinical applications (programmability)
2010s: - Insertion of pace maker via a leg catheter rather than via invasive surgery.
2014: - leadless pacing with the device so small it fits into the heart

1970s: Electrical safety issues lead to Clinical Engineering

‘Thousands of deaths expected from electrical currents through the heart during catheterization’

Discussions on (expensive) Isolated Power systems

First certified programs for ‘clinical engineers’ (and BMET’s)

1971 - Magnetic Resonance Imaging
1971 - Computed Tomography (CT Scan)
1972 - Insulin Pump
1973 - Laser Eye Surgery (LASIK)
1974 - Liposuction
1976 - First commercial PET scanner
1980 - First commercial MRI scan

… and an increasing need for understanding of high tech issues in the hospital

Safety issues

death from electrical currents ?

cancer from X-ray ?

damage from ultrasound radiation ?

birth control pills leading to child deformations

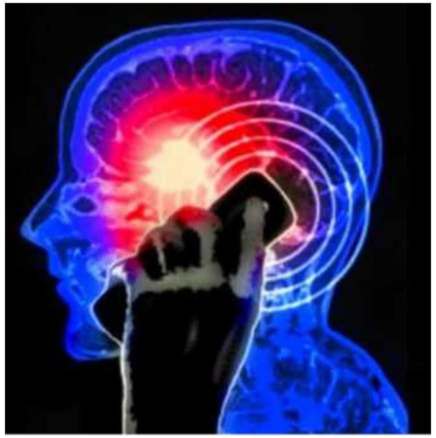
damage from high Tesla field strength ?

ALARA principle (As Low As Reasonably Achievable)

risk versus benefit

mobile phone damage to head / hearing ?

Electricity damage of HV lines ?



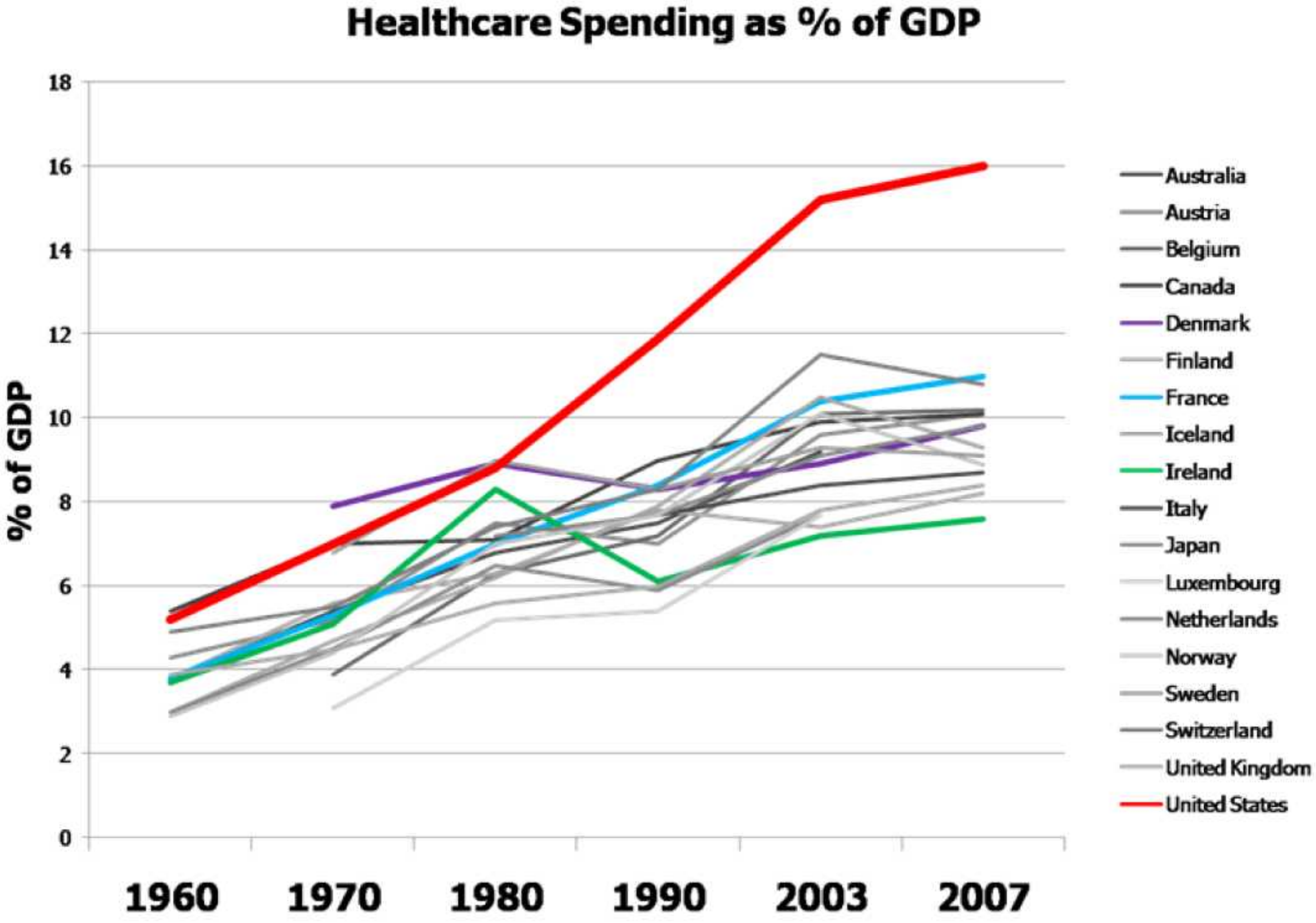
Increasingly high-tech healthcare

Maintenance costs of equipment turned out to be very high

3rd Party Maintenance Organizations

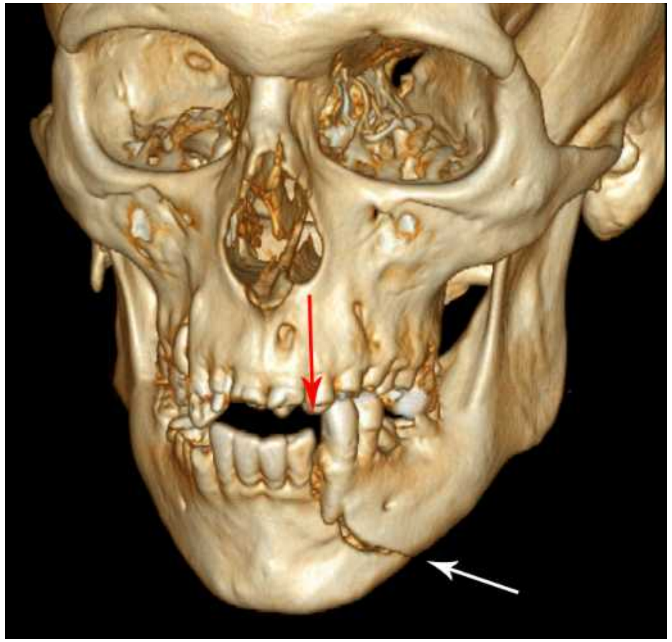
Continuous uptake of new technology

- Organ transplantations
- PACS systems, telemedicine
- PET/SPECT scanners, Gamma Knives, …



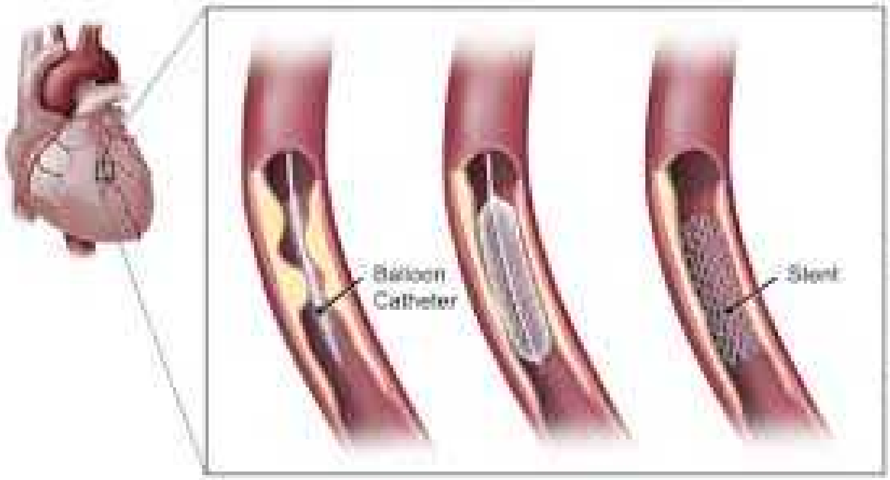
Innovations over the past decades (examples)

3Tesla MR systems



3D CT reconstructions

interventional techniques

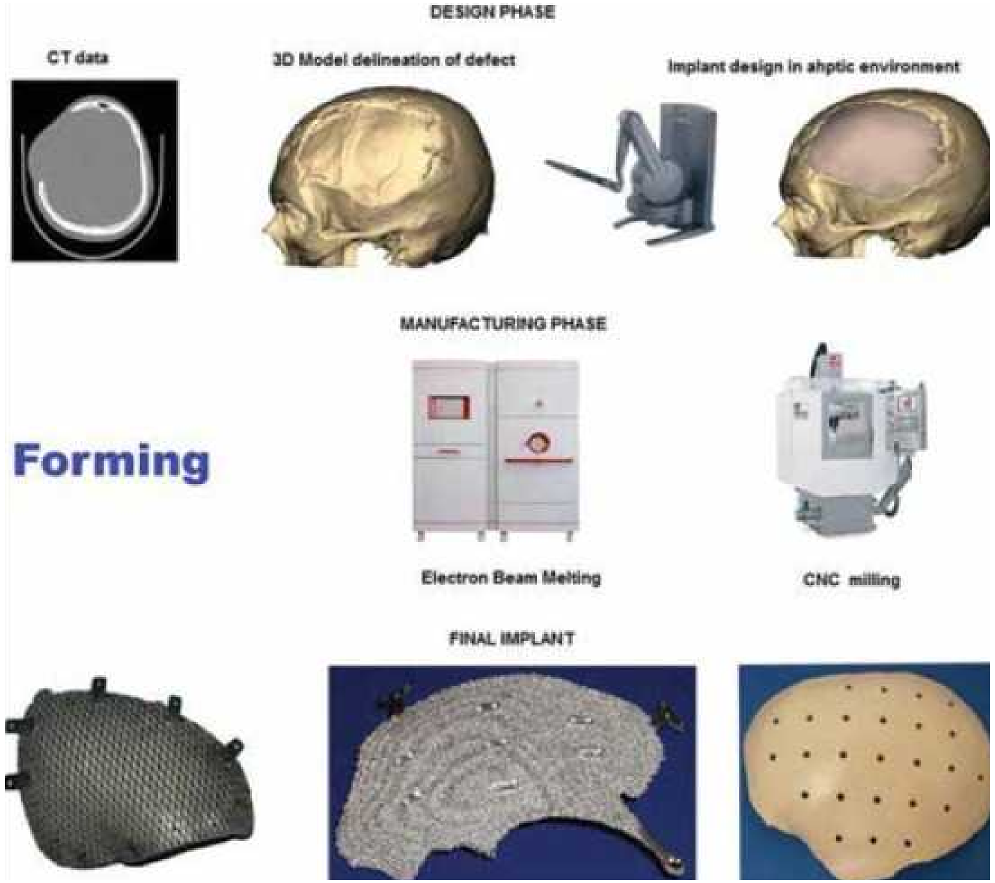


3D ultrasound

Current innovations (examples)

Surgical Robots,
Minimally invasive surgery,
Tele-surgery

Hybrid Operating
Rooms



Manufacturing of patient specific implants

Current innovations

Human Genome analysis: the recipe of how we are built

Human liver grown from stem cell

Digestible Sensors

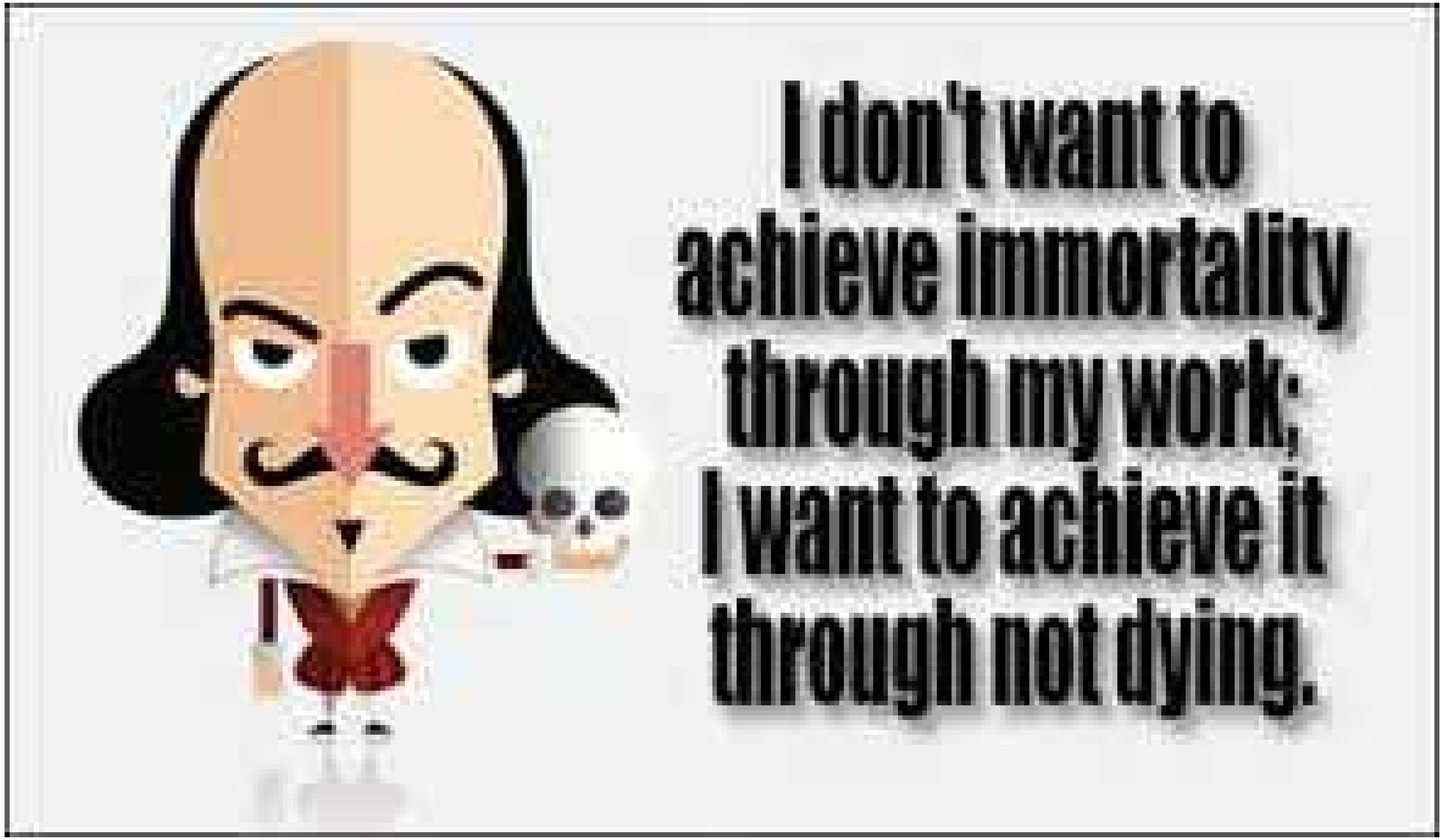
Future innovations

Analysis of personal DNA – via DNA chips - will lead to personalized cancer cures

The Human Brain Project is a large 10-year scientific research project, established in 2013, largely funded by the European Union, which aims to provide a human whole brain model within its 10 year funding period. Its total costs are estimated at €1.19 billion. A similar program is running in the USA.

Genetic manipulation promised to help overcome genetic diseases

An old wish to become reality ?



END

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PARTNERSHIPS FOR GLOBAL HEALTH