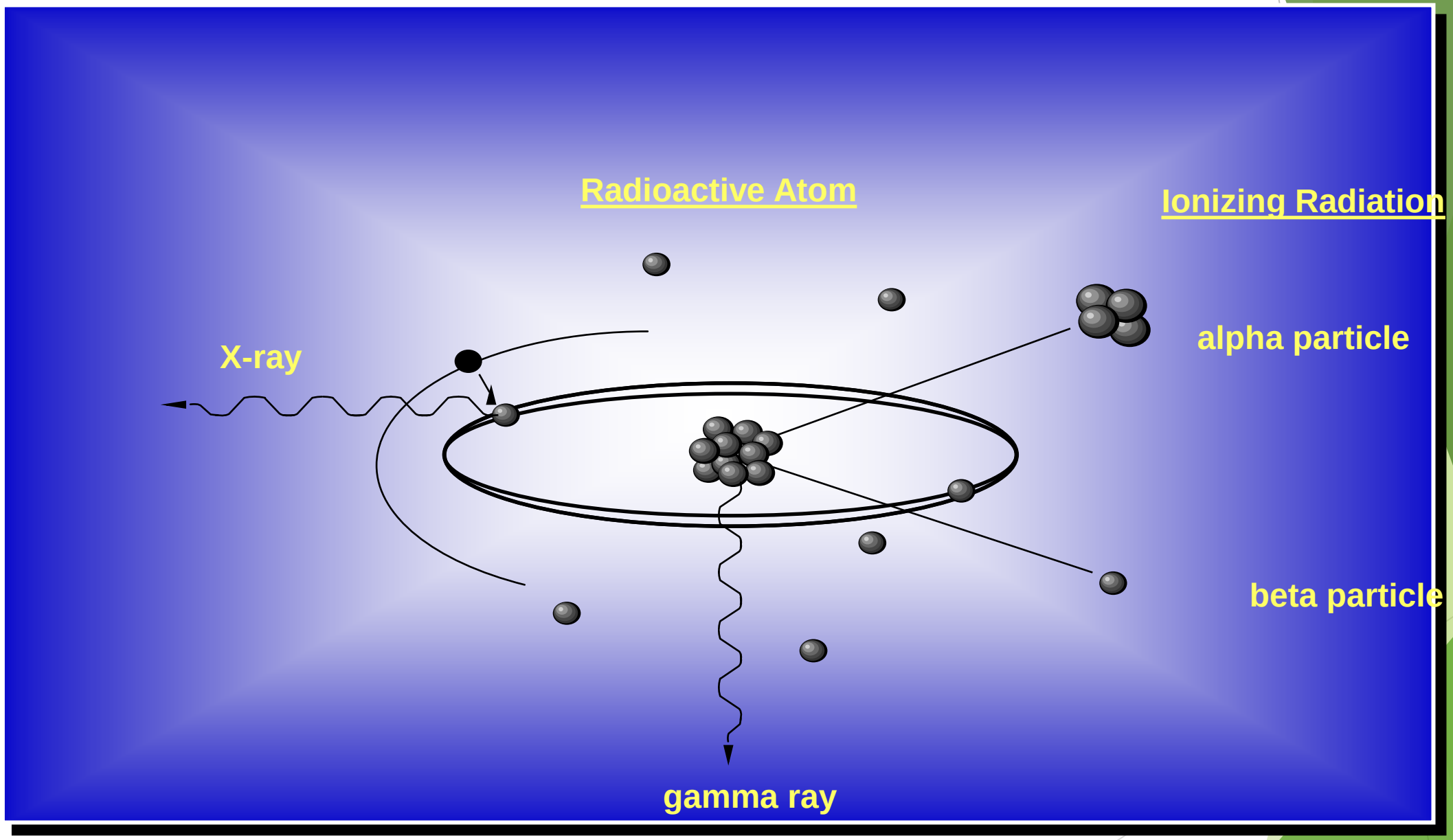
Ionizing radiation.
Action of ionizing radiation on biological objects.

Ionization

- Ionizing radiation is produced by unstable atoms. Unstable atoms differ from stable atoms because they have an excess of energy or mass or both.

- Unstable atoms are said to be radioactive. In order to reach stability, these atoms give off, or emit, the excess energy or mass. These emissions are called radiation.


Radioactive Atom
Ionizing Radiation
X-ray
alpha particle
beta particle
gamma ray

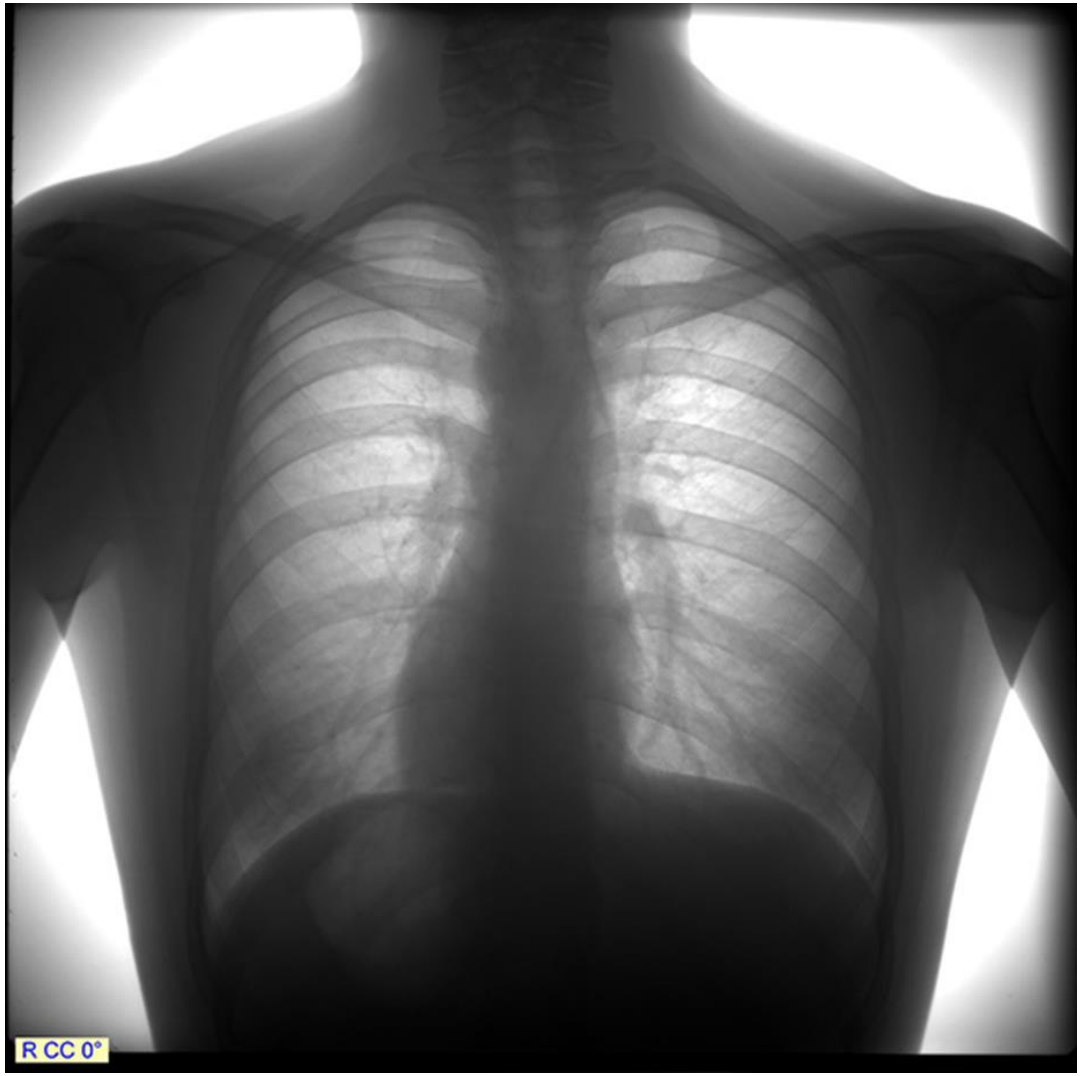
Four Primary Types of Ionizing Radiation

- Alpha particles
- Beta particles
- Gamma rays (or photons)
- X-Rays (or photons)
- Neutrons

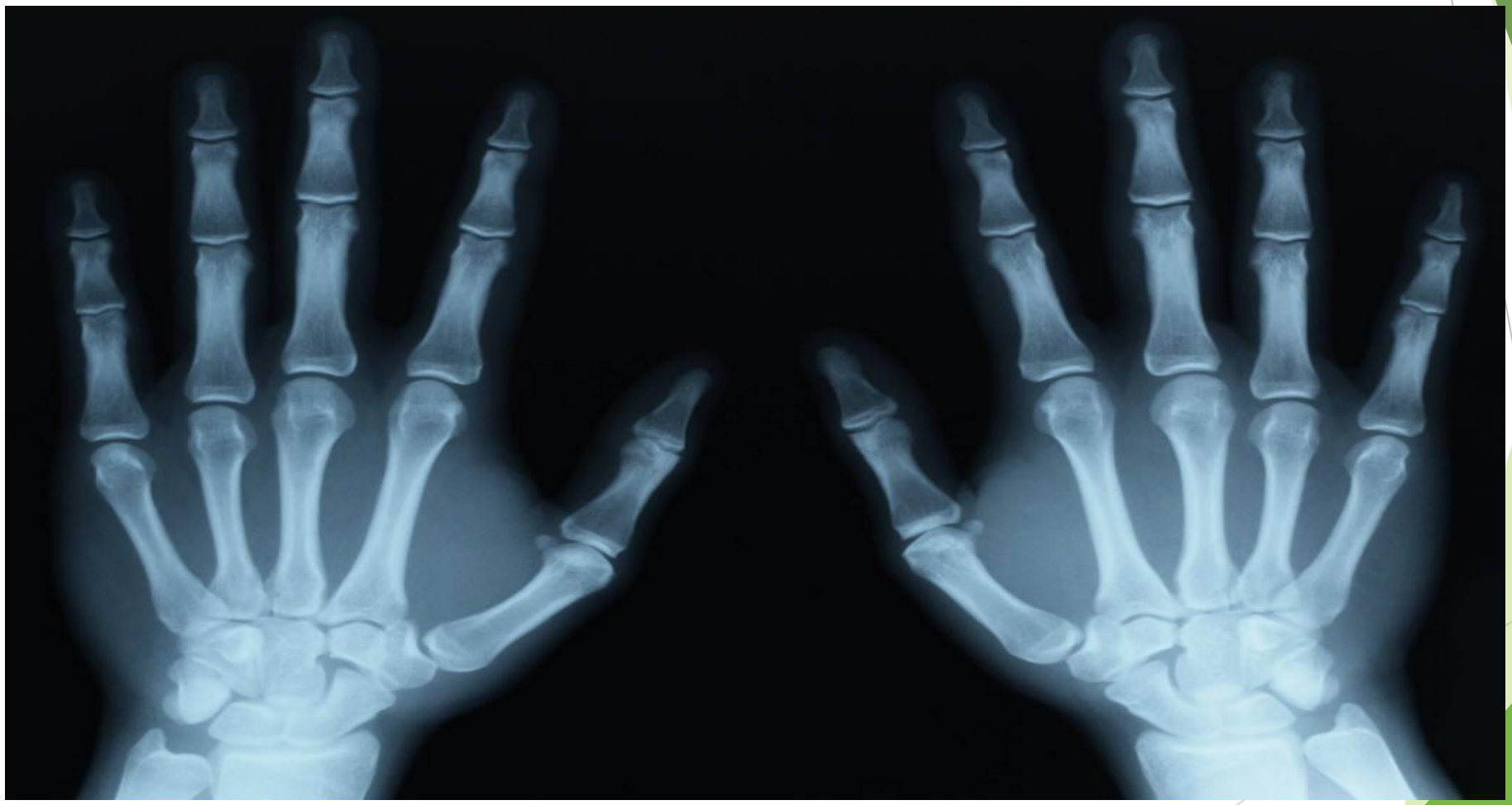
There are 3 main uses of **ionising radiation** in medicine:

- Treatment
- Diagnosis
- Sterilisation

Ionizing radiation.
x-rays and its uses in medicine



PICTURES OF X RAYS !



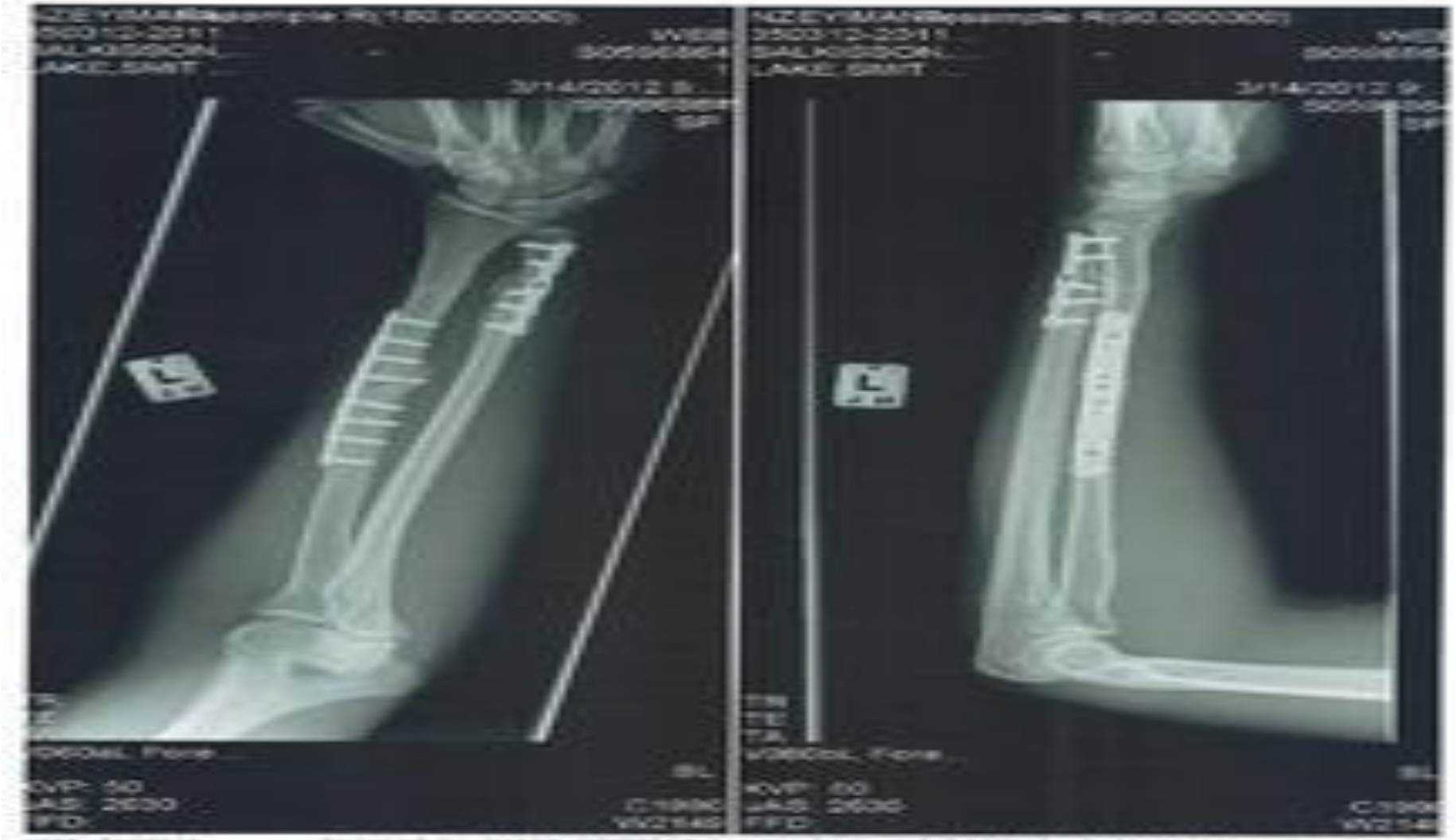
Four Primary Types of Ionizing Radiation: X-Rays

X-Rays: Occur whenever an inner shell orbital electron is removed and rearrangement of the atomic electrons results with the release of the elements characteristic X-Ray energy.

USAGE OF X RAY IN MEDICINE:

RADIOGRAPHS:

A radiograph is an X-ray image obtained by placing a part of the patient in front of an X-ray detector and then illuminating it with a short X-ray pulse. Bones contain much calcium, which due to its relatively high atomic number absorbs x-rays efficiently.



An arm radiograph, demonstrating broken ulna and radius with implanted internal fixation.

The nature of ionizing radiation its interaction numerically can be measured by the ratio of the energy passed to ionized element to the mass of it.
This characteristic is called radiation absorbed dose (D):

$$D = \frac{dE}{dm}$$

Unit: 1 rad= 0.01 Gy(grey)=0.01 J/kg

Equivalent dose is a dose quantity *H* representing the stochastic health effects of low levels of ionizing radiation on the human body.

It is derived from the physical quantity absorbed dose, but also takes into account the biological effectiveness of the radiation, which is dependent on the radiation type and energy.

$$H = k \cdot D$$

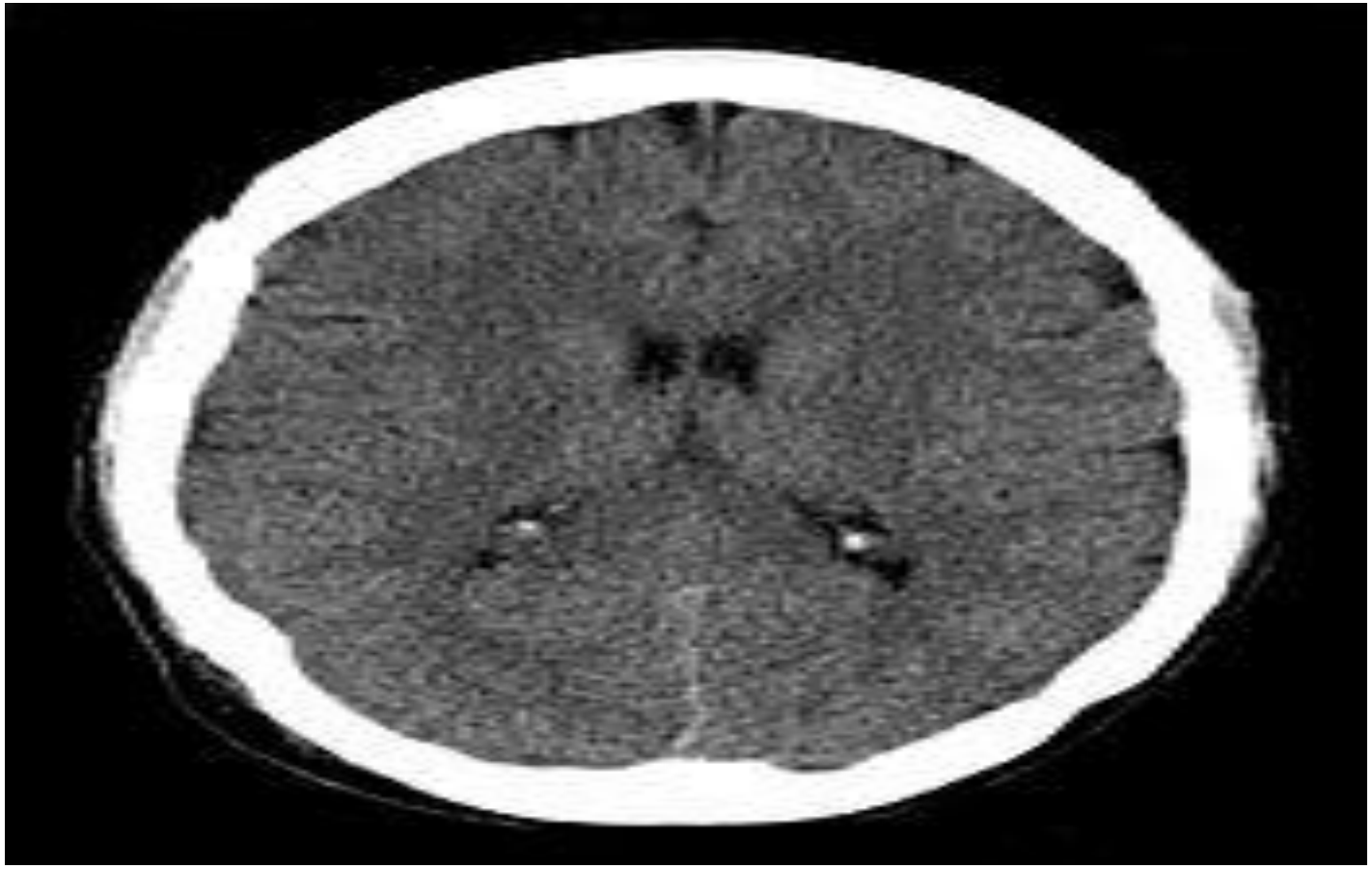
k - coefficient represents biological consequences of irradiation to human from energy transfer.

The unit of measure is the sievert (Sv).

COMPUTED TOMOGRAPHY:

Computed tomography (CT scanning) is a medical imaging modality where tomographic images or slices of specific areas of the body are obtained from a large series of two-dimensional X-ray images taken in different directions.

These cross-sectional images can be combined into a three-dimensional image of the inside of the body and used for diagnostic and therapeutic purposes in various medical disciplines.



Head CT scan (transverse plane) slice -- a modern application of medical radiography

Fluoroscopy

Fluoroscopy is an imaging technique commonly used by physicians or radiation therapists to obtain real-time moving images of the internal structures of a patient through the use of a fluoroscope.

In its simplest form, a fluoroscope consists of an X-ray source and fluorescent screen between which a patient is placed.

Radiotherapy

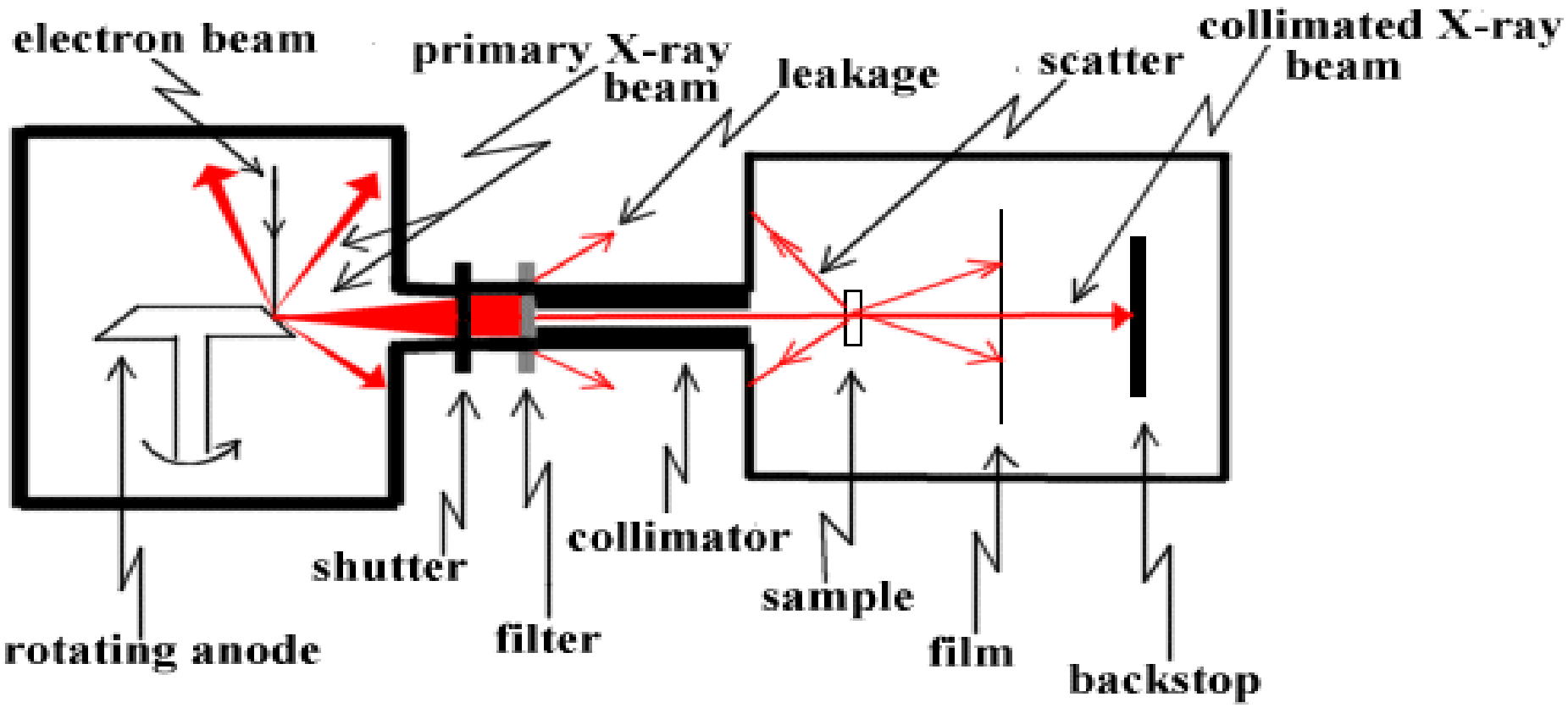
The use of X-rays as a treatment is known as radiation therapy and is largely used for the management (including palliation) of cancer;

It requires higher radiation doses than those received for imaging alone.

❖X-ray crystallography in which the pattern produced by the diffraction of X-rays through the closely spaced lattice of atoms in a crystal is recorded and then analysed to reveal the nature of that lattice. A related technique, fiber diffraction, was used by Rosalind Franklin to discover the double helical structure of DNA.

❖X-ray astronomy, which is an observational branch of astronomy, which deals with the study of X-ray emission from celestial objects.

❖X-ray microscopic analysis, which uses electromagnetic radiation in the soft X-ray band to produce images of very small objects.


electron beam
primary X-ray beam
leakage
scatter
collimated X-ray beam
shutter
collimator
rotating anode
filter
sample
film
backstop

❖X-ray fluorescence, a technique in which X-rays are generated within a specimen and detected. The outgoing energy of the X-ray can be used to identify the composition of the sample.

❖Industrial radiography uses X-rays for inspection of industrial parts, particularly welds.

❖Industrial CT (computed tomography) is a process which uses X-ray equipment to produce three-dimensional representations of components both externally and internally. This is accomplished through computer processing of projection images of the scanned object in many directions.

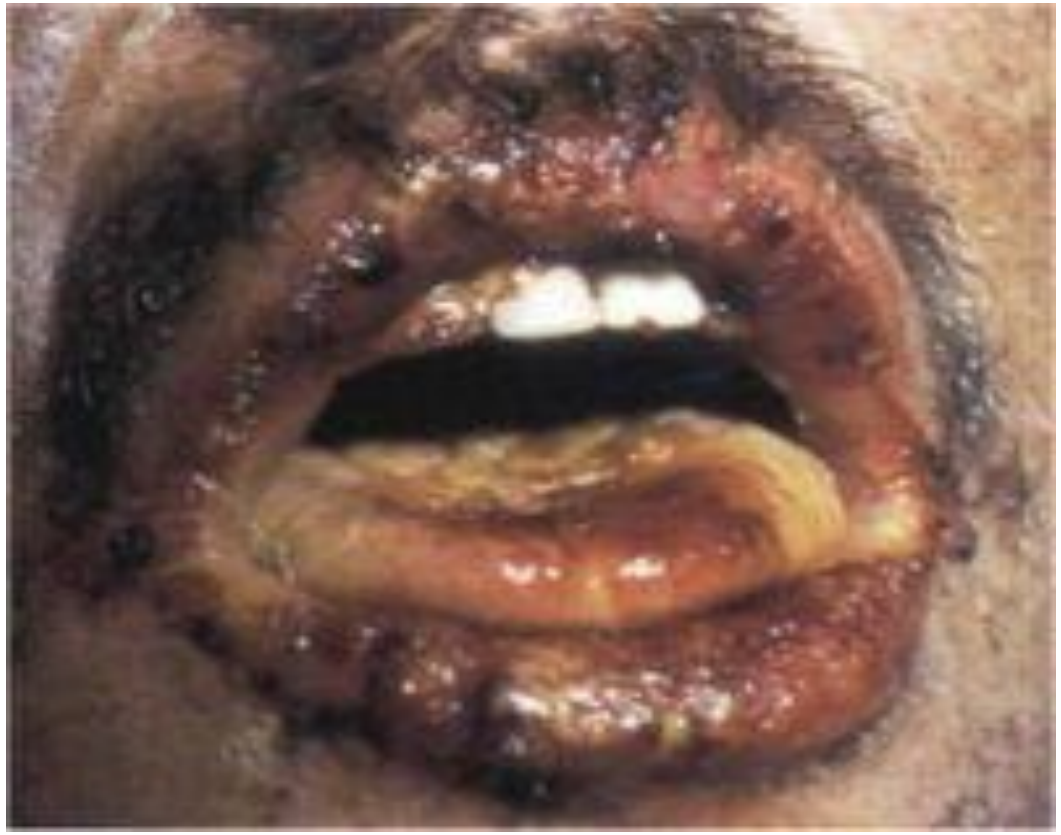
X-Ray Multi-Energy Introscopy Systems with New Semiconductor Scintillators

- Theoretical background and data on the ways of practical realization are presented, related to the problem of detection of dangerous organic objects (explosives, drugs, etc.) in the presence of other organic substances with atomic number differing by no more than 20-30%.

- For this purpose, multi-energy X-ray introscopy is used. It has been shown that the "weakest link" in the existing multi-energy introscopes used for safety inspection and medicine are detectors of ionizing radiation.

Ionizing radiation hazard symbol

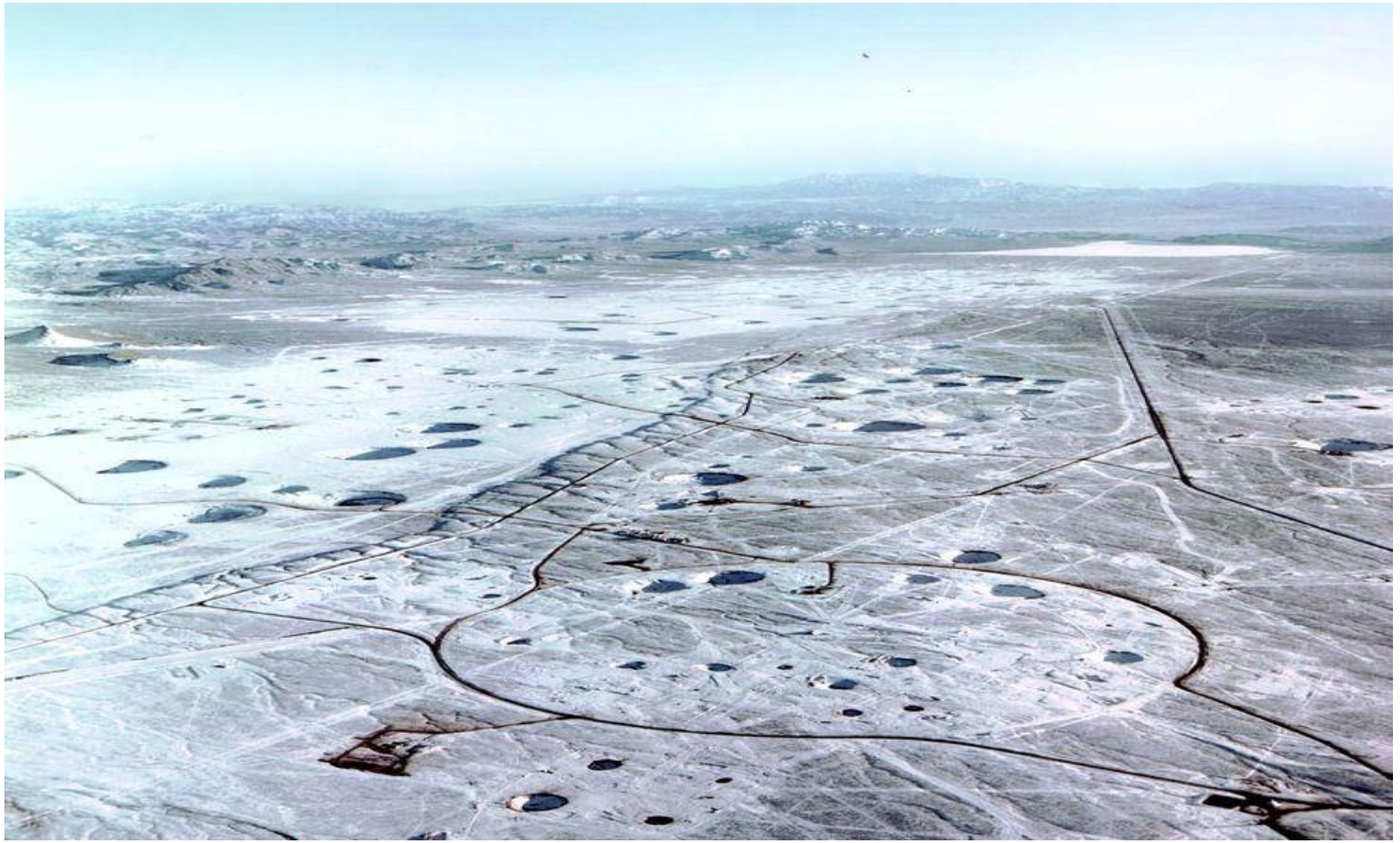
Biological Effects of Ionising Radiation



The mouth of a man who has suffered a 10 to 20 Gy dose 21 days after the exposure, note that damage to normal skin, the lips and the tongue can be seen.

Biological Effects of Ionising Radiation

The crater-scarred landscape of the Nevada Test Site.



Magnetic Resonance Imaging (MRI)

What is MRI?

- Produces very clear, detailed pictures of the organs and structures in the body
- It is a form of medical imaging that uses no Ionizing radiation
- MRI makes use of the property of Nuclear magnetic resonance (NMR) to image nuclei of atoms inside the body.

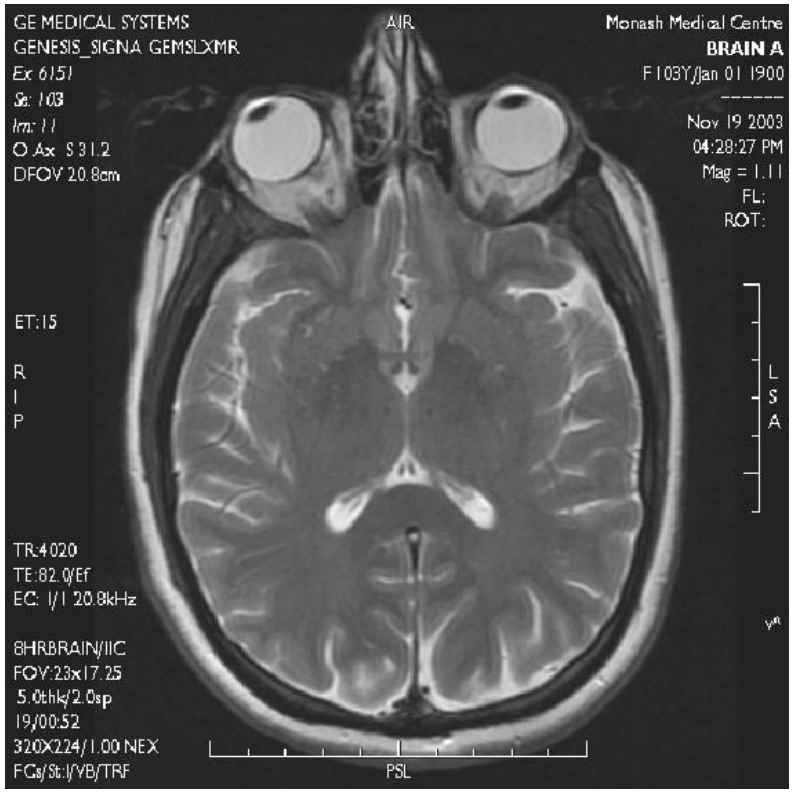
History

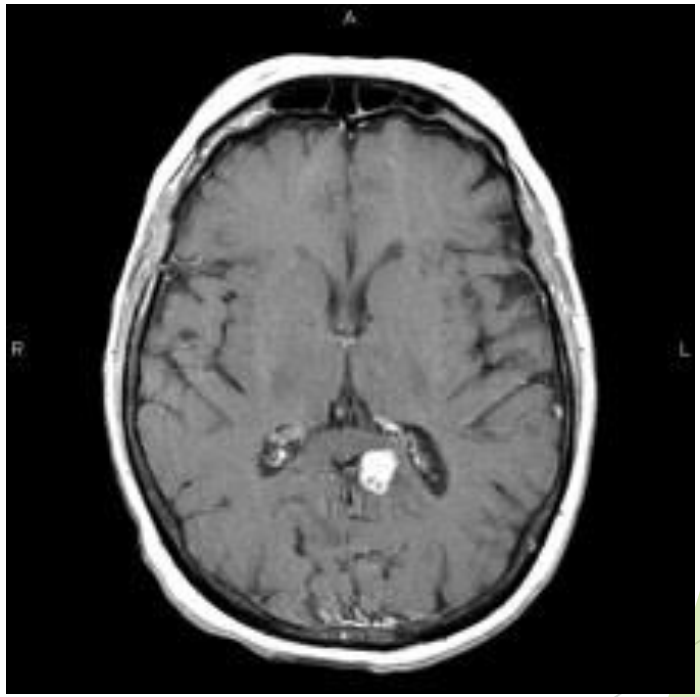
- The first MR image was published in 1973
- The first studies performed on humans were published in 1977
- Created by Dr. Raymond V. Damadian, Dr. Larry Minkoff and Dr. Michael Goldsmith
- In 2003, The 2003 Nobel Prize in Physiology or Medicine was awarded to Paul C Lauterbur and Peter Mansfield
  - Made new MR imaging techniques
  - Faster and more efficient

Common Uses

- Physicians use the MR examination to help diagnose or monitor treatment for conditions such as:
  - Tumors and other cancer related abnormalities.
  - Certain types of heart problems.
  - Blockages or enlargements of blood vessels
  - Diseases of the liver, such as cirrhosis, and that of other abdominal organs.
  - Diseases of the small intestine, colon, and rectum

Common Uses

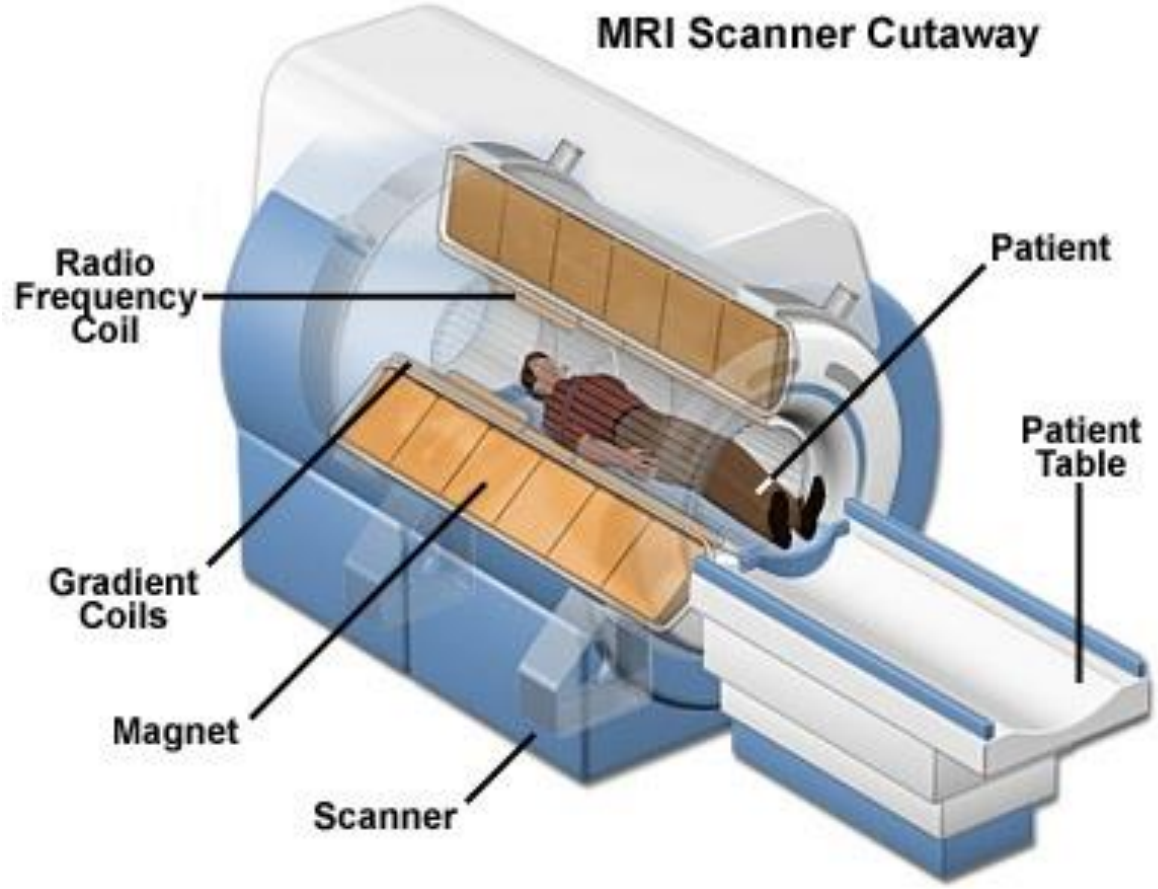

GE MEDICAL SYSTEMS
GENESIS_SIGNA GEMSLXMR
Ex 6151
Se: 103
Im: 11
O Ax S 31.2
DFOV 20.8cm
AIR
Monash Medical Centre
BRAIN A
F 103Y/Jan 01 1900
Nov 19 2003
04:28:27 PM
Mag = 1.11
FL:
ROT:
ET:15
R
I
P
L
S
A
TR:4020
TE:82.0/Ef
EC: 1/1 20.8kHz
8HRBRAIN/IIC
FOV:23x17.25
5.0thk/2.0sp
19/00:52
320X224/1.00 NEX
FGs/St:I/YB/TRF
PSL


A
R
L

How does it work?

- An MRI machine uses a powerful magnetic field to align the magnetization of some atoms in the body.
  - radio frequency fields systematically alter the alignment of this magnetization
- This causes the nuclei to produce a rotating magnetic field detectable by the scanner
  - This information is recorded to construct an image of the body.

How does it work?



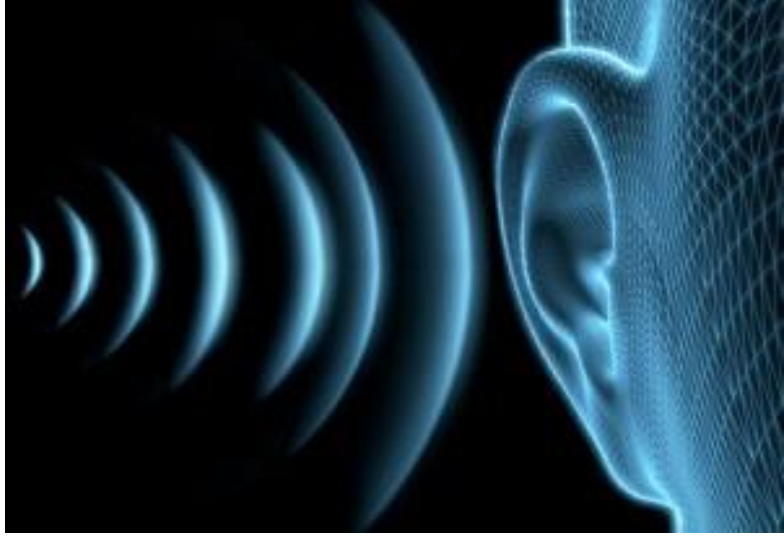
How does it work?

- Images are constructed when protons in different tissues return to equilibrium state at different rates.
- Five variables effect these rates
  - Spin Density: Concentration of nuclei in tissue processing in a given region under a magnetic field.
  - T_1: Longitudinal relaxation time
  - T_2: Transverse relaxation time
  - Flow: Shows blood flow, CSF flow
  - Spectral Shifts: Angle/zoom the picture is taken from.


THANK YOU

Sound research methods of biological systems

Plan of lesson:



1) What is sound?
2) Range of sound waves
3) Physical sound settings
4) the wave properties of sound waves
5) Acoustics
6) Ultrasound
7) Methods for obtaining ultrasound
8) Using of ultrasound in medicine

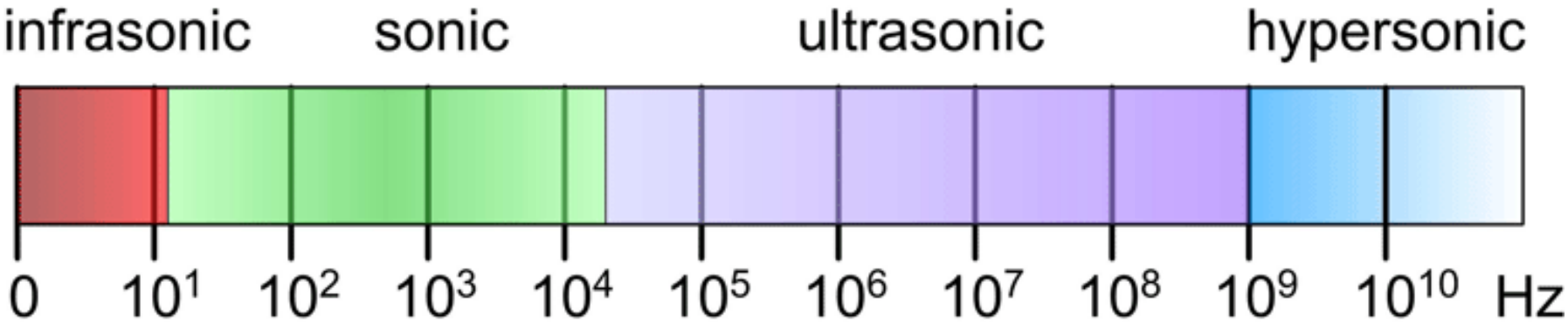
What is sound?

- **Sound -** a natural phenomenon, which is a distribution in the form of *elastic waves of mechanical vibrations* in a solid, liquid or gaseous medium.

- Like any wave, the sound is characterized by the amplitude and the frequency spectrum.

Range of sound waves

- The average person is able to hear the sound vibrations in the frequency range from 16-20 Hz to 15-20 kHz.
- Sound below human hearing range is called *infrasound*; above: to 1 GHz - *ultrasound* of 1 GHz - *hypersonic*.



Physical sound settings

- **Sound velocity** - the speed of propagation of sound waves in the medium.

- In ideal conditions, average speed of sound in air is 340-344 m / s

In general, the speed of sound c is given by the Newton–Laplace equation:

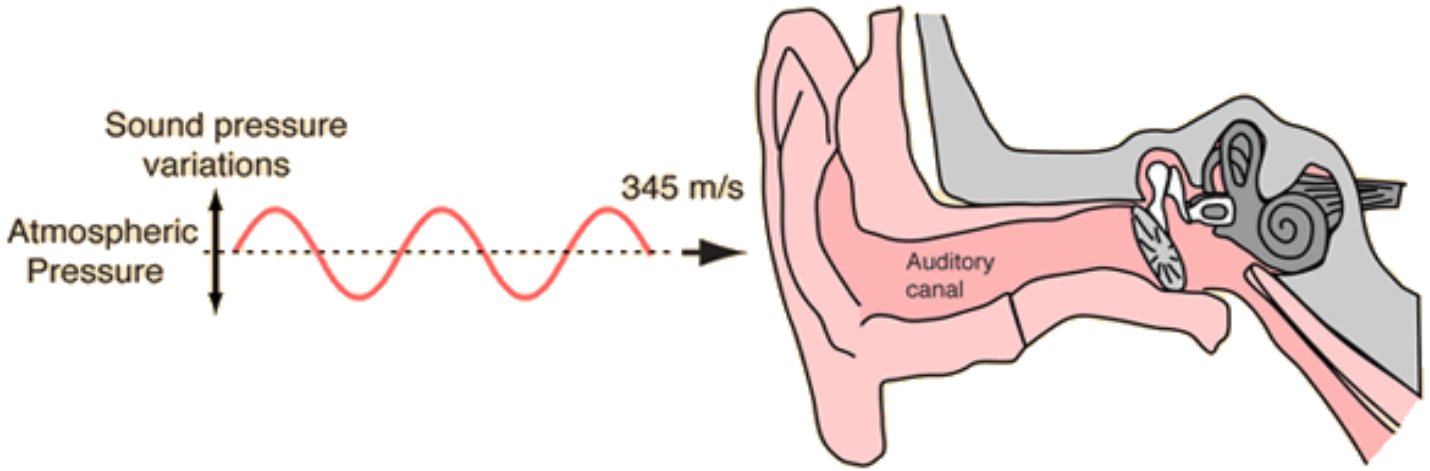
$$c = \sqrt{\frac{K_s}{\rho}}$$

where

- K_s is a coefficient of stiffness, the isentropic bulk modulus (or the modulus of bulk elasticity for gases);
- ρ is the density.

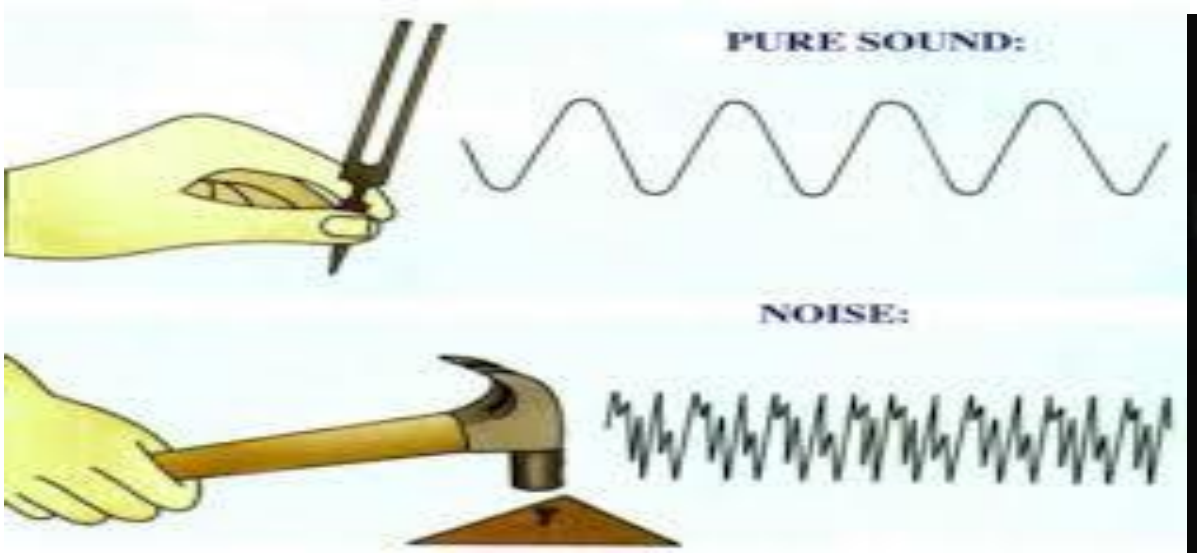
Physical sound settings

- **The volume of sound** - the subjective perception of sound intensity (absolute value of the auditory sensations).
- The volume is mainly dependent *on the sound pressure*, *amplitude* and *frequency* of the sound vibrations.

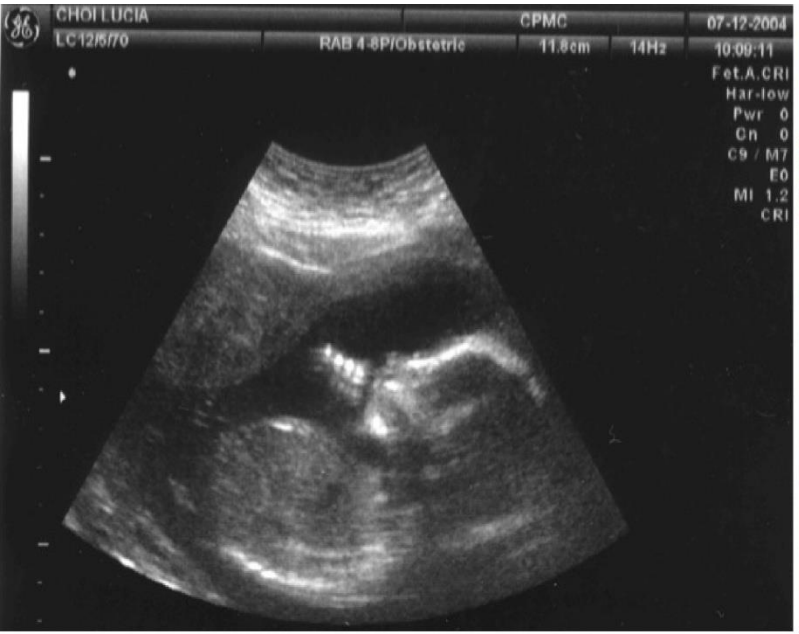


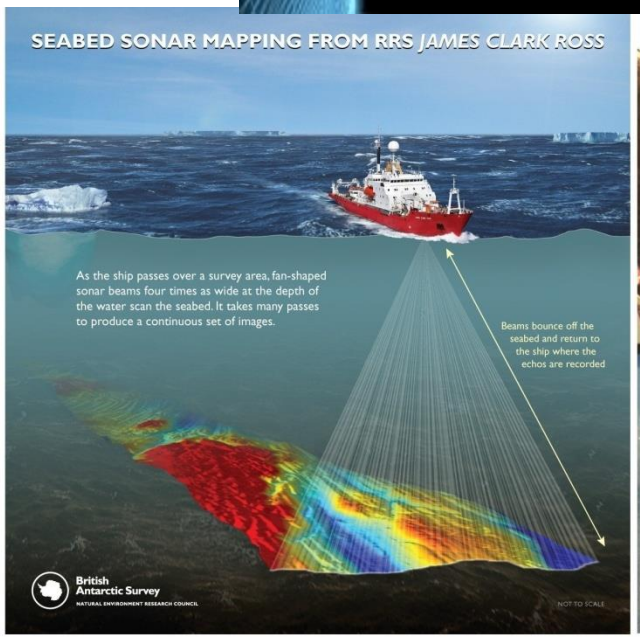
Generation of sound

- For the generation of sound used vibrating body with different nature, causing fluctuations in the ambient air.
- An example of this generation is the use of the vocal cords, speakers or fork. Most musical instruments based on the same principle.



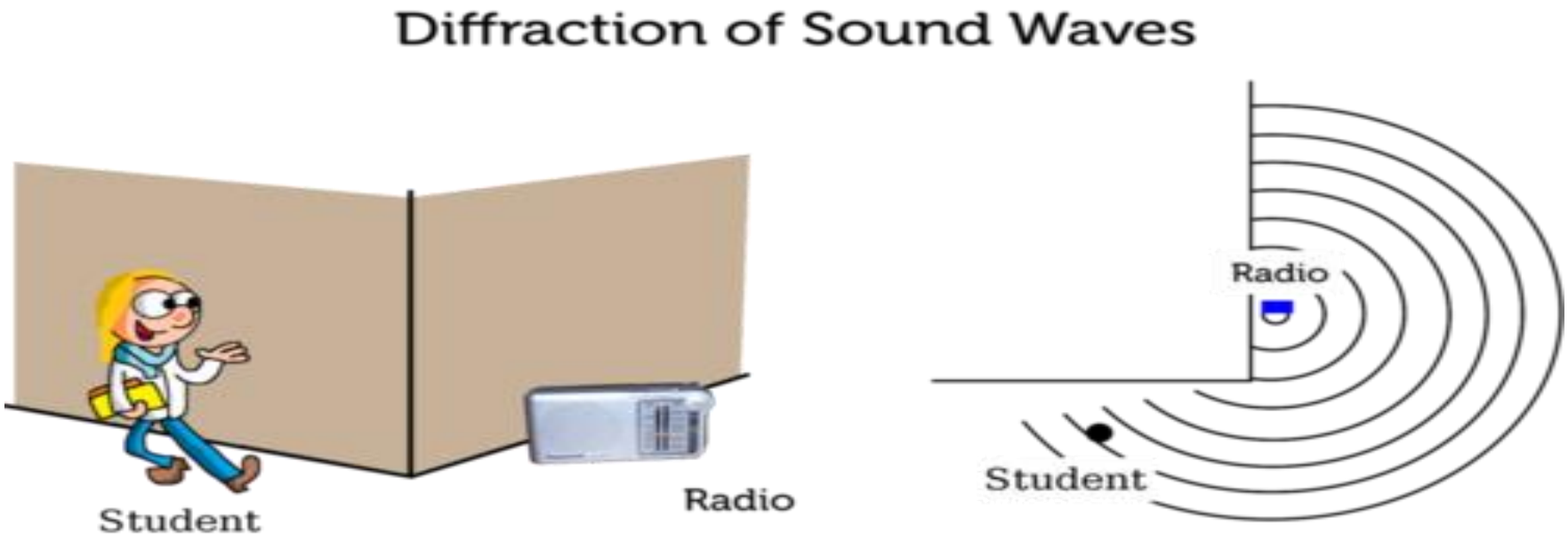
Sound, like light, a source of information, and in that its main significance.





In the propagation of ultrasonic waves are possible effects of diffraction, interference and reflection.

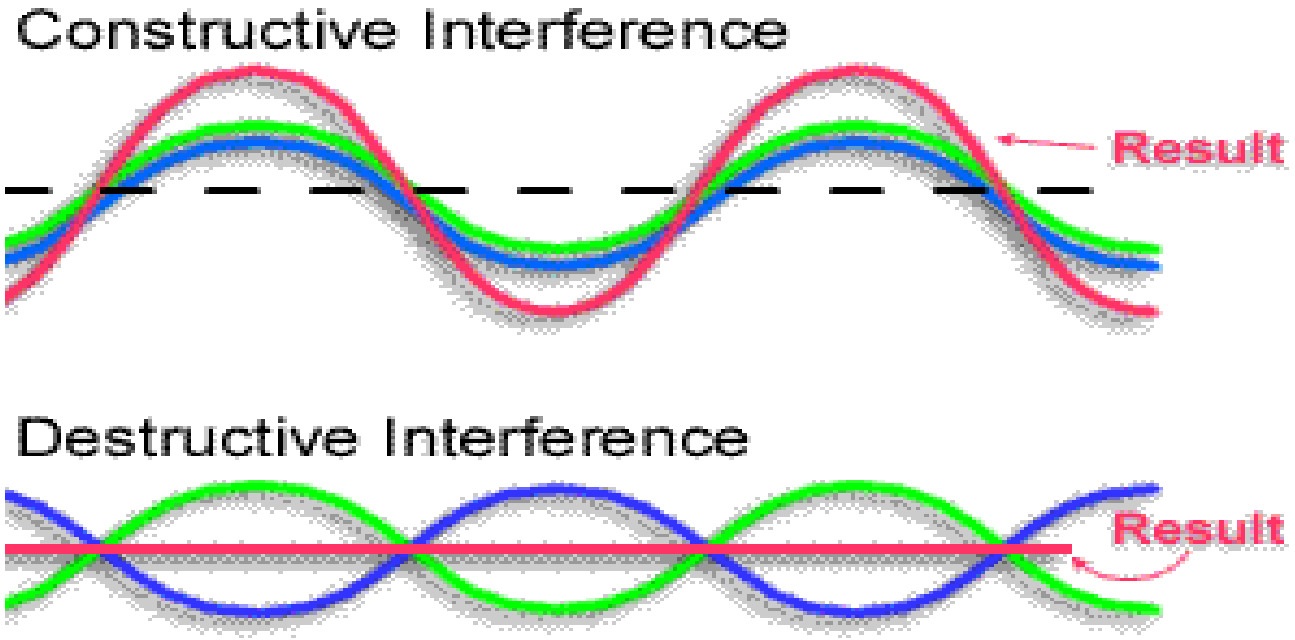
Diffraction (bending of waves of obstacles) occurs when the length of the ultrasonic wave is comparable (or better) with the size of the obstacles in the path. If the obstacle is compared with the acoustic wavelength is large, then there is the phenomenon of diffraction.



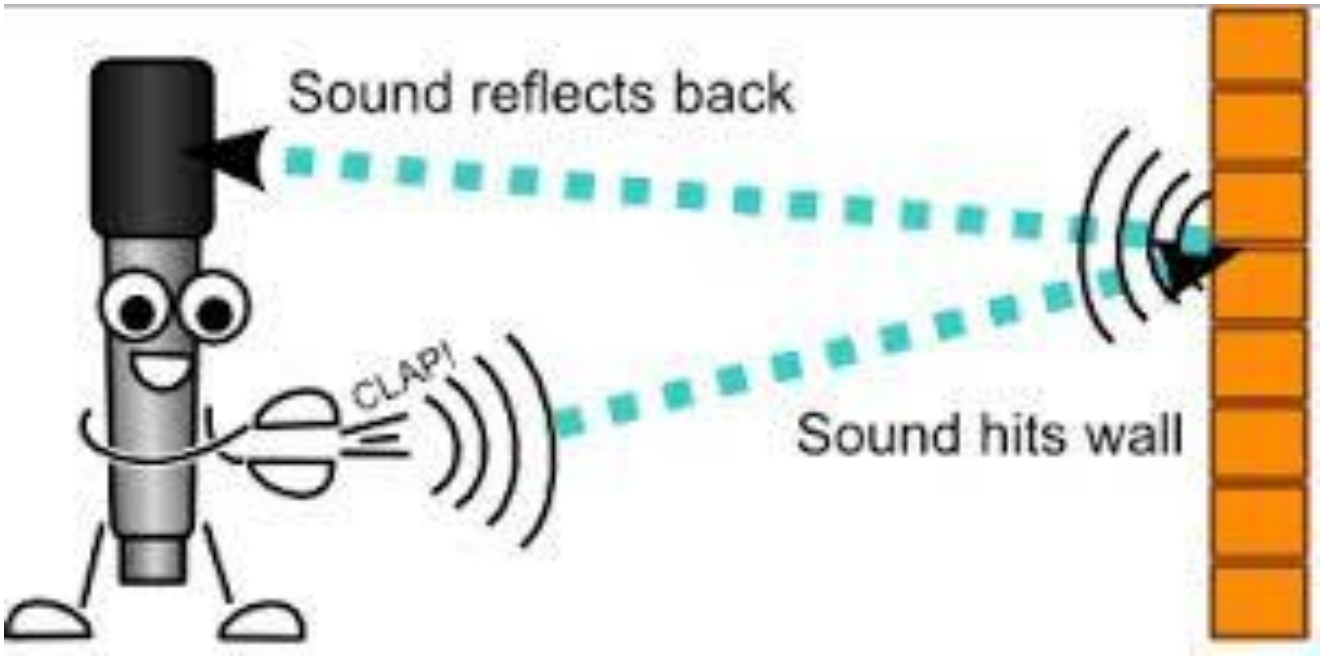
With simultaneous movement among multiple ultrasonic waves in each specific point of the medium occurs superposition of these waves.

Imposing waves of the same frequency with each other is called **interference.**

If in the process of passing through the object, the ultrasonic waves intersect, in certain points of the medium is *observed increase or decrease vibrations.*



•When a wave reaches the boundary between one medium with another medium, a portion of the wave undergoes **reflection** and a portion of the wave undergoes transmission across the boundary, the amount of reflection is dependent upon the dissimilarity of the two media.



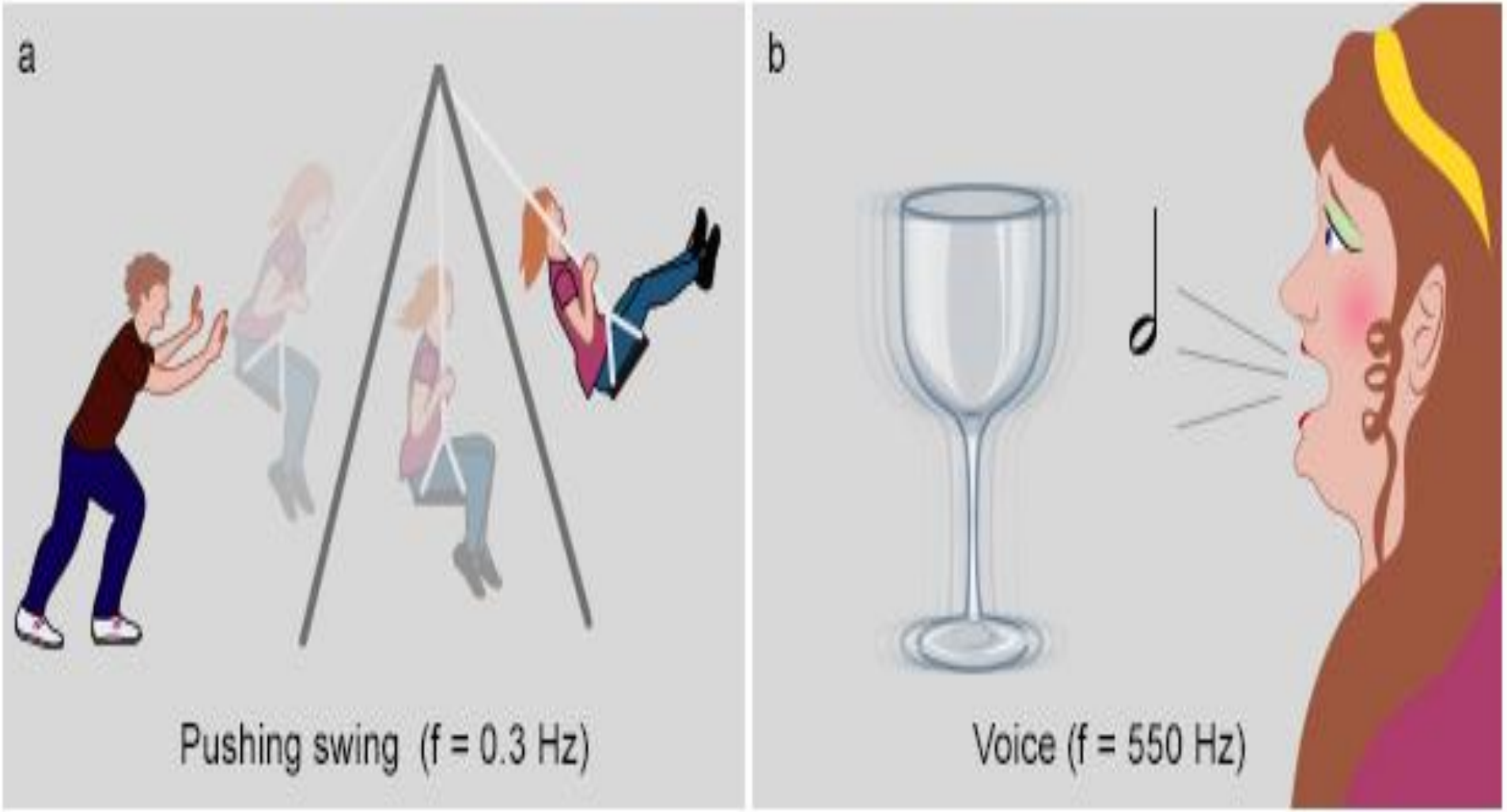
- ***Resonance*** - this phenomenon is the emergence and strengthening of oscillation of a body or a part thereof under the action of the exciting these vibrations of an external force, the impact of frequency coincides with the natural resonant frequency of the body.

- Strings instruments such as guitar, violin or piano, have their own resonant frequency, is directly dependent on the length and strength of the string tension.

- *The first resonance wavelength* of the string *is equal to twice its length.*

- Thus, its frequency depends on the velocity $\boldsymbol{v}$, with which the wave propagates along the string.

Resonance: just add energy (... at the right frequency)



Acoustics

Acoustics is defined as

(a) Science of sound, including its production, transmission, and effects, including biological and psychological effects.

(b) Those qualities of a room that, together, determine its character with respect to auditory effects.

The study of acoustics revolves around the generation, propagation and reception of mechanical waves and vibrations.

Ultrasound

- Ultrasound - sound waves having a frequency above the human ear is typically understood by ultrasound frequencies above 20,000 hertz.

- In our time, ultrasound is widely used in a variety of physical and technological methods.

- Thus, the sound propagation speed in the medium is judged on its physical characteristics.

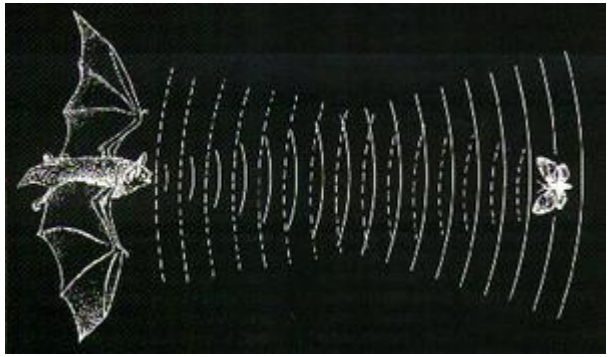
Sources of ultrasound

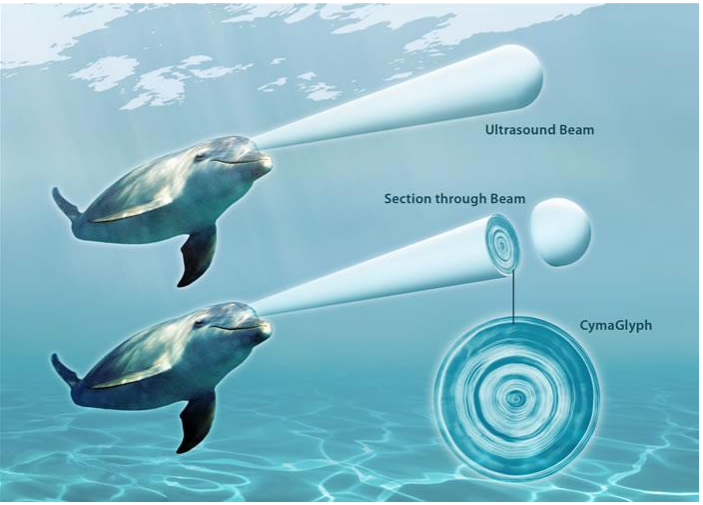
- High frequency vibrations are usually produced by means of piezoelectric transducers, for example of barium titanite.

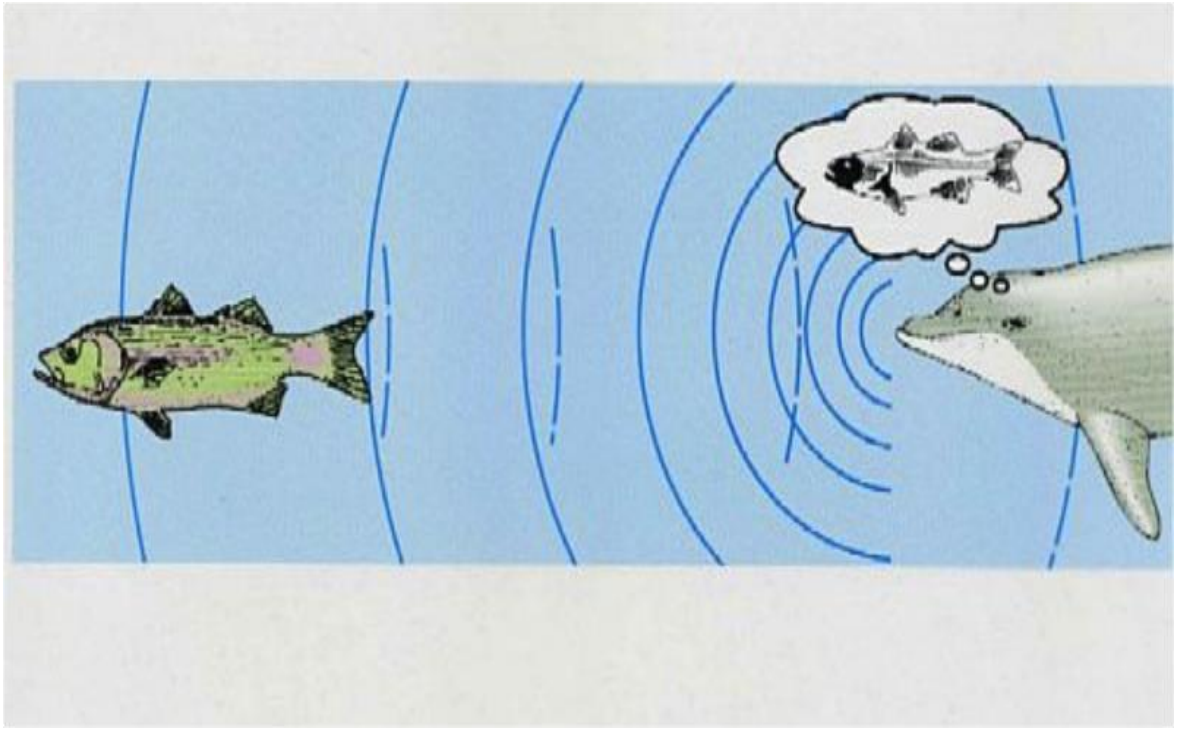
- In those cases when primary importance is the power of ultrasonic vibrations, commonly used mechanical sources of ultrasound (tuning forks, whistles and sirens).

- In nature, ultrasound occurs both as a component of many natural noise (the noise of the wind, waterfalls, rain, sea surf rolls, in the sound of lightning), and among the wildlife sounds.

- Some animals use ultrasonic waves to detect obstacles, orientation in space and communication (whales, dolphins, bats, rodents).







- Ultrasound emitters can be divided into two large groups:

- Emitters generators; fluctuations in them are excited by the presence of obstacles in the way of constant flux - a jet of gas or liquid.

- Electroacoustic transducers; they convert already given fluctuations of voltage or current into a mechanical oscillation of the solid body which emits into the environment acoustic waves

Biomedical ultrasound applications generally can be divided into two areas: diagnostic and research and methods of influence.

- The first direction are locating methods and the use of pulsed radiation.
- It echoencephalography - defining tumors and cerebral edema;
- ultrasound cardiography - measure heart size in dynamics;
- in ophthalmology - ultrasonic location to determine the size of the eye media.
- With the help of an ultrasonic Doppler effect study the nature of the motion of the heart valves and measure the velocity of blood flow.
- For diagnostic purposes on the ultrasound velocity are the density accrete or damaged bone.

- A second area relates ultrasound physiotherapy.
- Patient sonicated using a special device head emissivity.

- Typically, for therapeutic purposes applied ultrasound frequency of 800 kHz, the mean intensity of about 1 W / cm2 or less.

- The primary mechanism of ultrasound therapy is a mechanical and thermal effect on the tissue.

- In operations ultrasound is used as "ultrasonic scalpel" that can cut and soft and bone tissues.

- The ability of the ultrasound to crush the body placed in a fluid to create an emulsion and used in the pharmaceutical industry in the manufacture of drugs.

- in the treatment of diseases such as tuberculosis, asthma, catarrh of the upper respiratory tract, aerosols apply different drug substances obtained by sonication.

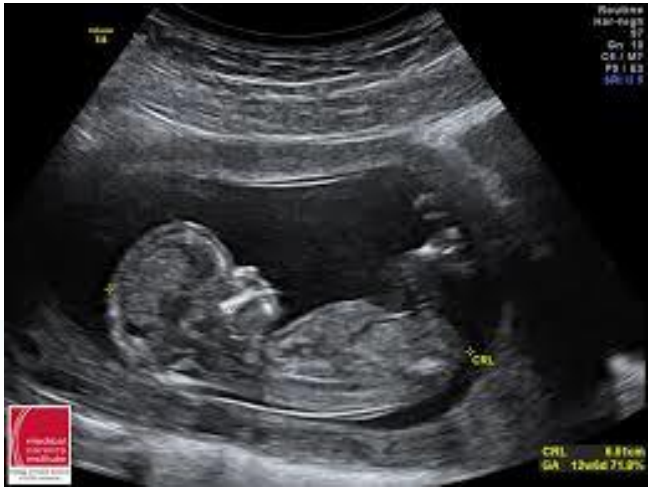
- Currently, a new method of "welding" damaged or transplanted bone tissue by means of ultrasound (ultrasound osteosynthesis).

- Interestingly the use of ultrasound for the blind. Through ultrasonic location using a portable device "Landmark" can detect objects and determine their character at a distance up to 10 m.

WHAT IS SONOGRAPHY

- It's a diagnostic medical procedure that uses high frequency sound waves
- To see images of organs, tissues, or blood flow inside the body.
- examine many parts of the body, such as the abdomen, breasts,
- female reproductive system, prostate, heart, and blood vessels.
- Detected heart disease,heart attack,&vascular disease that can lead to stroke

Ultrasonography



The therapeutic use of ultrasound in medicine

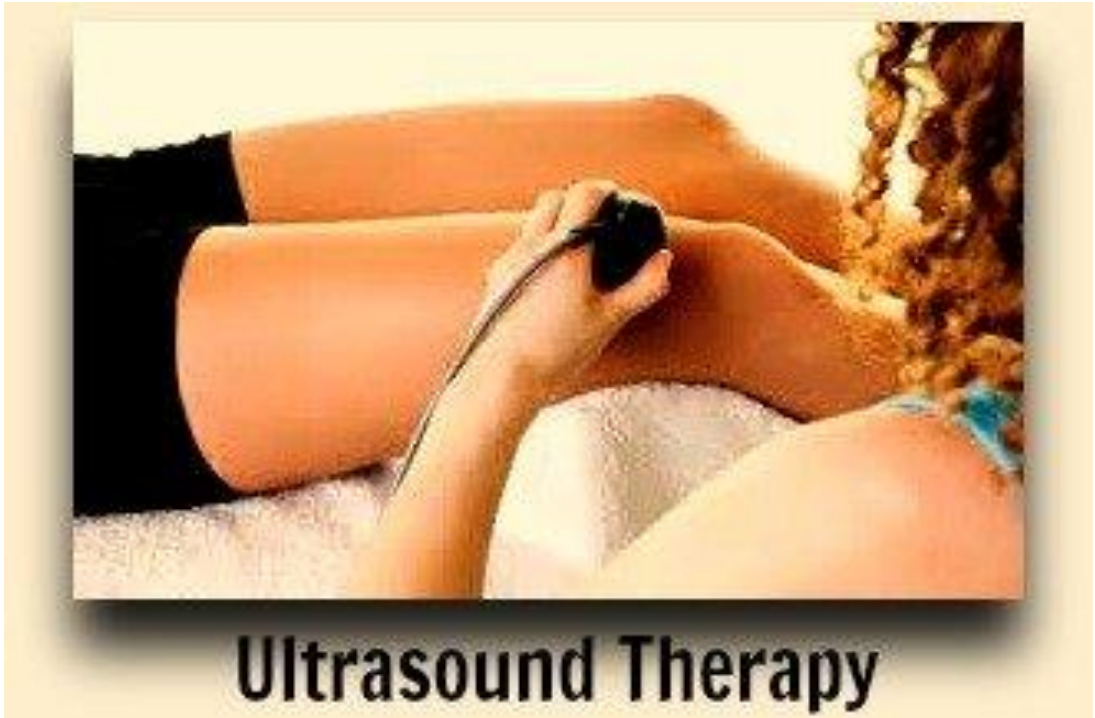
- In addition to the widespread use for diagnostic purposes, ultrasound is used in medicine as a treatment tool.

- Ultrasound has the following effects:

- anti-inflammatory, resolving the action;
- analgesic;
- cavitation increased permeability of the skin.

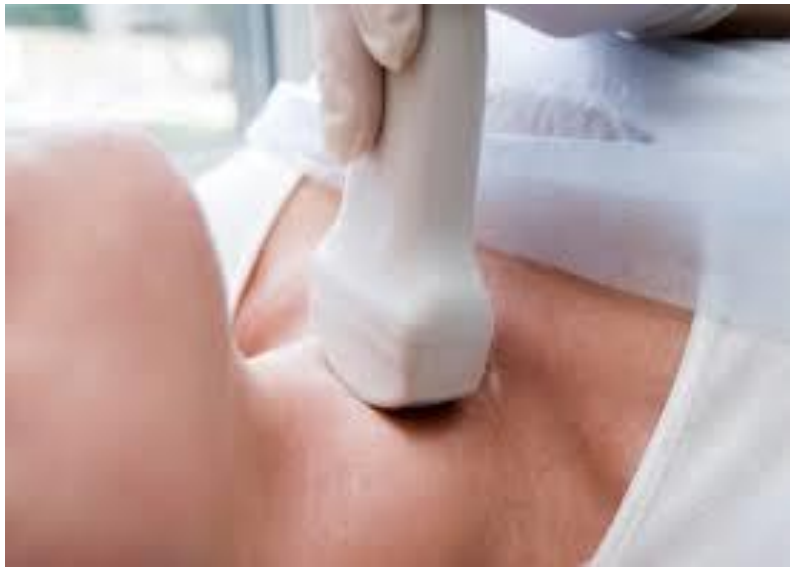
- Ultrasound therapy involves high-frequency sound vibrations creating heat that can minimize pain sensations. It can treat several conditions such as fibromyalgia, arthritis and other musculoskeletal injuries.

- The process is usually performed during occupational, manipulation therapy and physical therapy wherein it creates heat to affected cells and tissues.



- Some of the known benefits are the reduction of nerve root irritation, healing enhancement without irritation, minimize chronic inflammation and swelling and enhancement of the natural healing processes of the body.

- Overall, ultrasound therapy is considered very safe and useful.

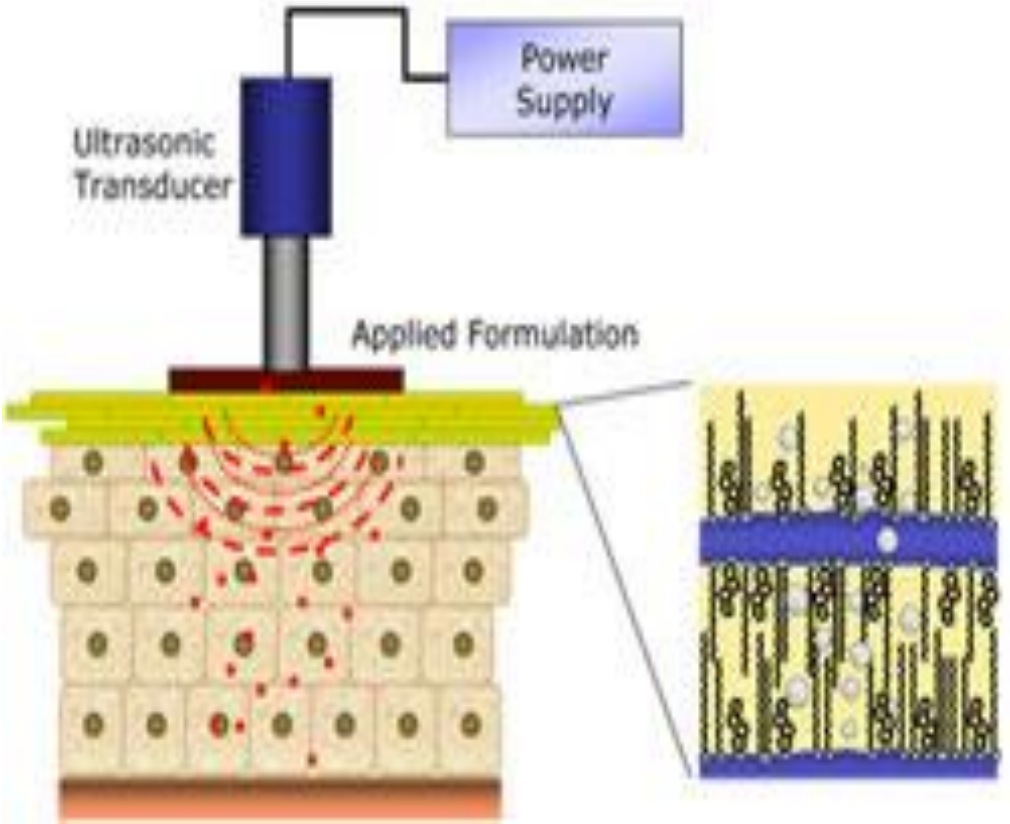


- It has a number of risks, like the possibility of patients to have burns.

- Individuals should consult their doctor first before attempting to receive therapeutic ultrasound.

Phonophoresis

- Phonophoresis - combined method of treatment, in which on the fabric instead of a conventional gel for ultrasound emission (used, for example, by ultrasound) is applied therapeutic agent (such as medications and substances of natural origin).
- It is assumed that the therapeutic ultrasound helps substance to penetrate deeper into the tissues.



The use of ultrasound in cosmetology

- Multifunctional beauty aids, generating ultrasonic vibrations at a frequency of 1 MHz, are used for the regeneration of skin cells and stimulate them metabolizm.
- Ultrasonic micromassage improves produced cells, blood circulation and lymph drainage. As a result, increases the tone of the skin, subcutaneous tissues.
- Ultrasound massage helps release of biologically active substances, eliminate the spasm of the muscles, resulting in wrinkles, tightens the face and body tissue.
- With the help of ultrasound is performed most profound introduction cosmetics and medicines, as well as toxins and purified cells.

- Naturally, the sound can be a source of information about the condition of internal organs.
- A common method for diagnosing diseases by the sound - **auscultation** (listening).
- For auscultation uses a **stethoscope**.
- Stethoscope consists of a hollow capsule 1 with two transmitting sound membrane applied to the patient's body, it goes from the rubber pipes 2 to the doctor's ear. The hollow capsule there is an air column resonance, resulting in enhanced sound quality and improved auscultation.

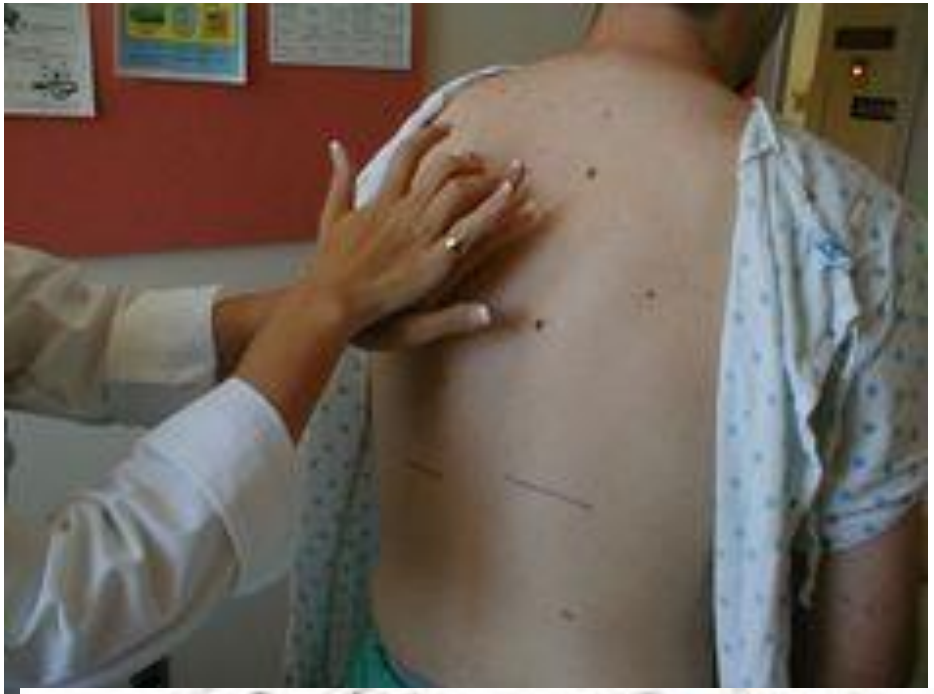
- Auscultation of the lungs listen to breath sounds, wheezing different characteristic of the disease.
- By changing tones of the heart and cause noise car judge the state of the heart. With auscultation, you can establish the presence
- of peristalsis of the stomach and intestines,
- to listen to the fetal heartbeat.

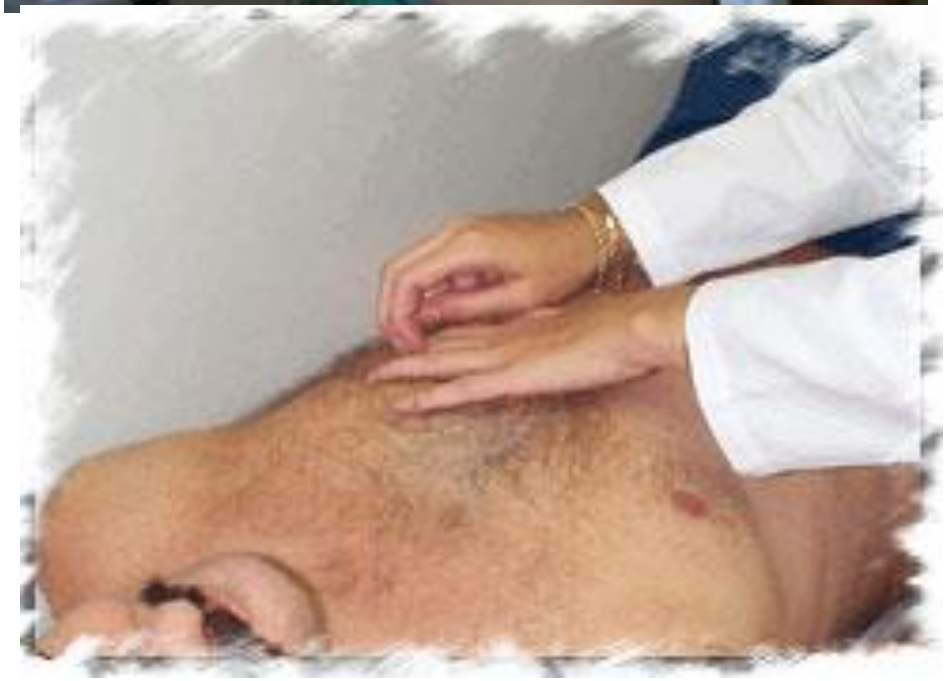
Percussion

- Percussion (Latin percussio, strikes.) –

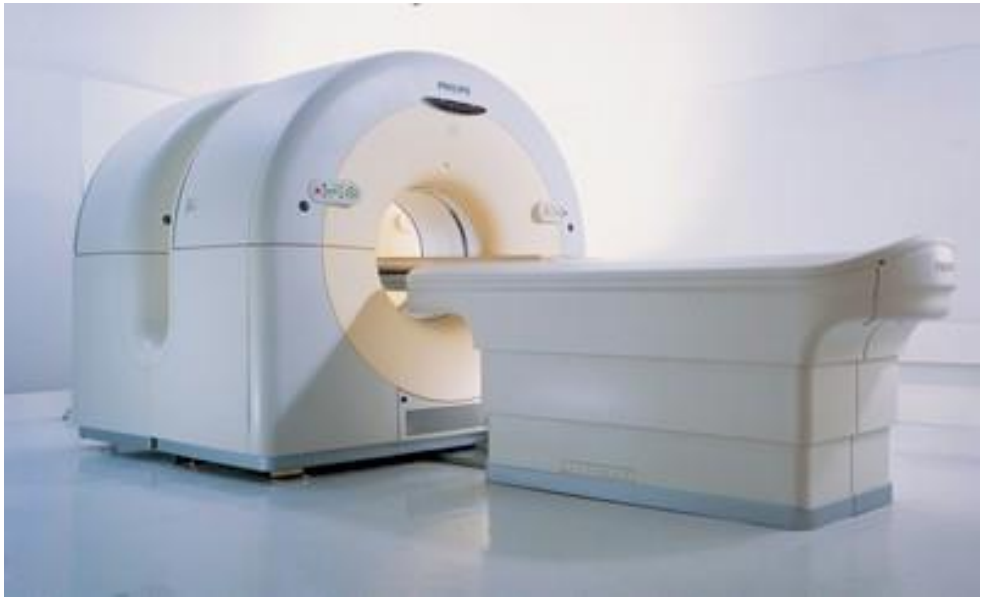
  a physical method of medical diagnostics comprising rapping certain areas of the body and analyzing the sounds arising from this. By the nature of the sound properties the doctor will determine the topography of the internal organs, physical condition and part of their function.

- A diagnostic procedure designed to determine the density of a body part by the sound produced by tapping the surface with the finger or a plessor; performed primarily over the chest to determine presence of normal air content in the lungs and over the abdomen to evaluate air in the loops of intestine and the size of solid organs such as the liver and spleen.





POSITRON EMISSION TOMOGRAPHY



Definition

A positron emission tomography is a nuclear medical imaging technique which produces a three dimensional image of functional processes in the body.

How it works

A short lived radioactive tracer isotope, is injected in to the living subject (usually in to blood circulation) . The tracer is chemically incorporated in to a biologically active molecule.

↓

There is a waiting period while the active molecule becomes concentrated in tissues of interest.

↓

As the radioisotope undergoes positron emission decay (also known as positive beta decay), it emits a positron, an antiparticle of the electron with opposite charge.

↓

After traveling up to a few millimeters the positron encounter an electron.

↓

The encounter annihilates them both, producing a pair of (gamma) photon moving in opposite directions.

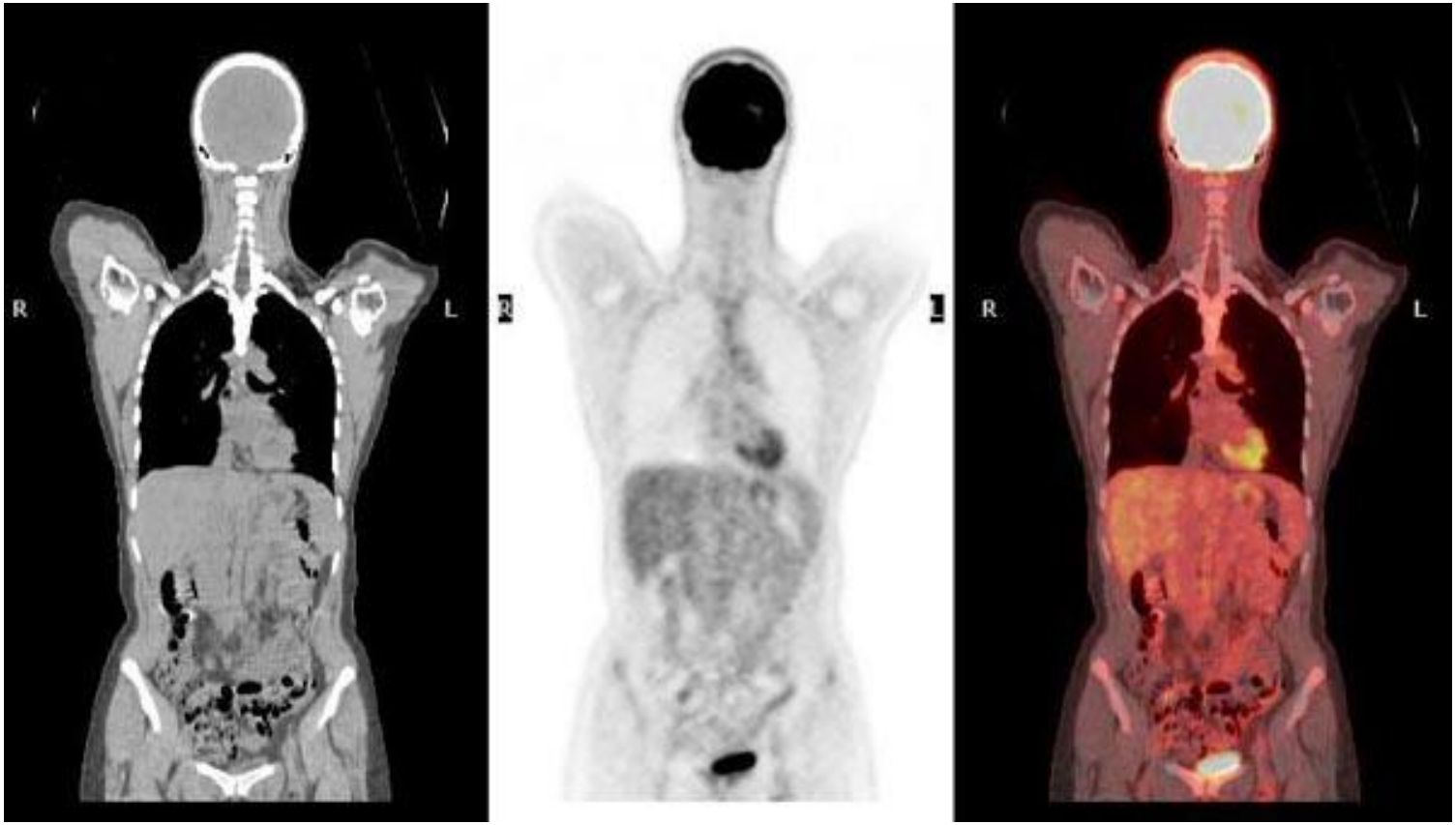
↓

These are detected when they reach scintillator in the scanning device creating a burst of light which is detected by photomultiplier tubes.

↓

The technicians can then create an image of the parts of your brain, for example which are overactive.

PET SCAN



Uses

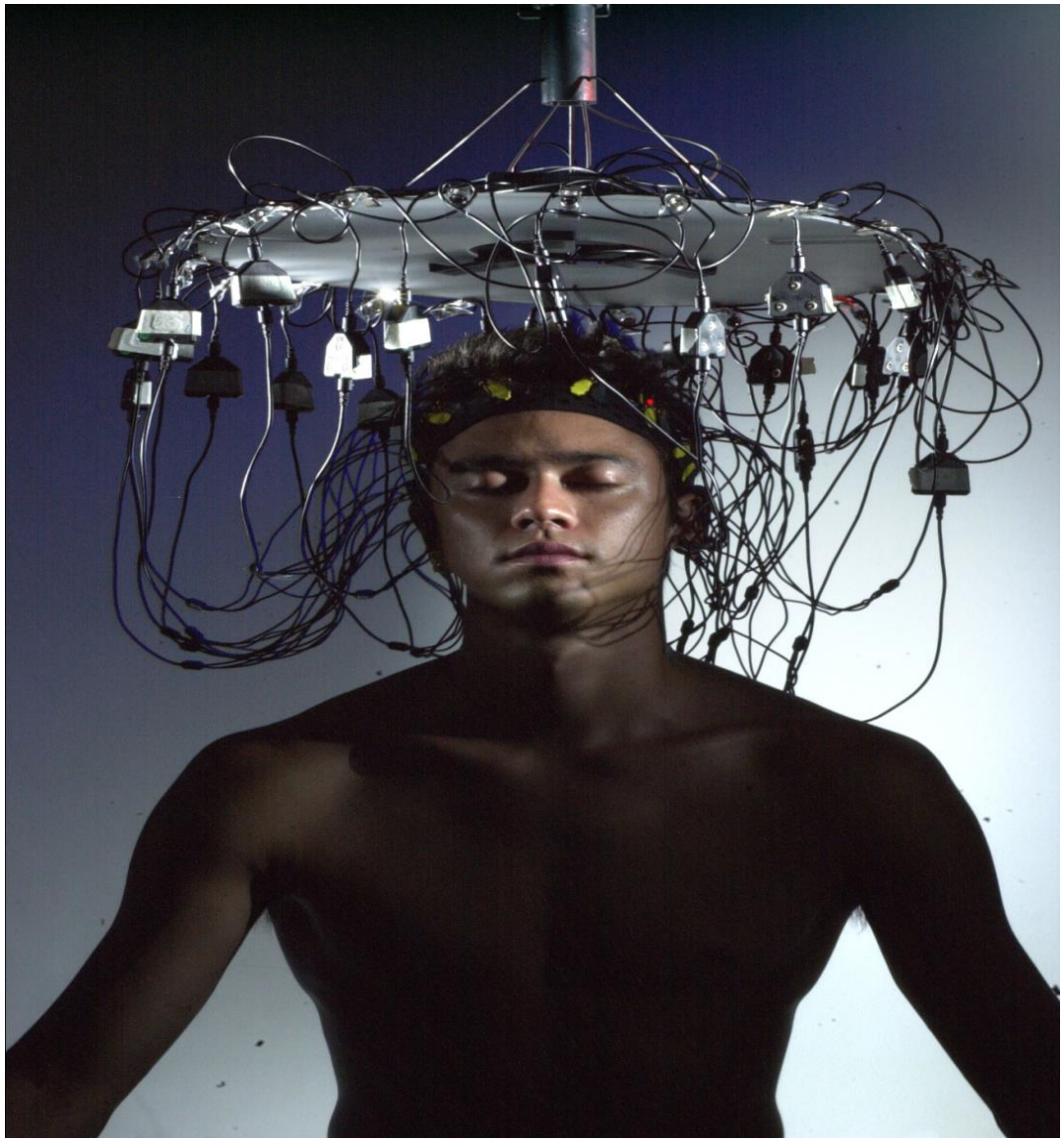
- Detect cancer.
- Determine whether a cancer has spread in the body.
- Assess the effectiveness of a treatment plan, such as cancer therapy.
- Determine if a cancer has returned after treatment.
- Determine blood flow to the heart muscle.
- Determine the effects of a heart attack, or myocardial infarction, on areas of the heart.
- Identify areas of the heart muscle that would benefit from a procedure such as angioplasty or coronary artery bypass surgery (in combination with a myocardial perfusion scan).
- Evaluate brain abnormalities, such as tumors, memory disorders and seizures and other central nervous system disorders.
- To map normal human brain and heart function.

THANK YOU FOR YOUR ATTENTION!!!

The concept of electroexcitability.

The Resting potential.

The Action potential.



Questions:

1. Introduction to biopotentials
2. The Resting Potential
3. The Action Potential
4. Measurement methods

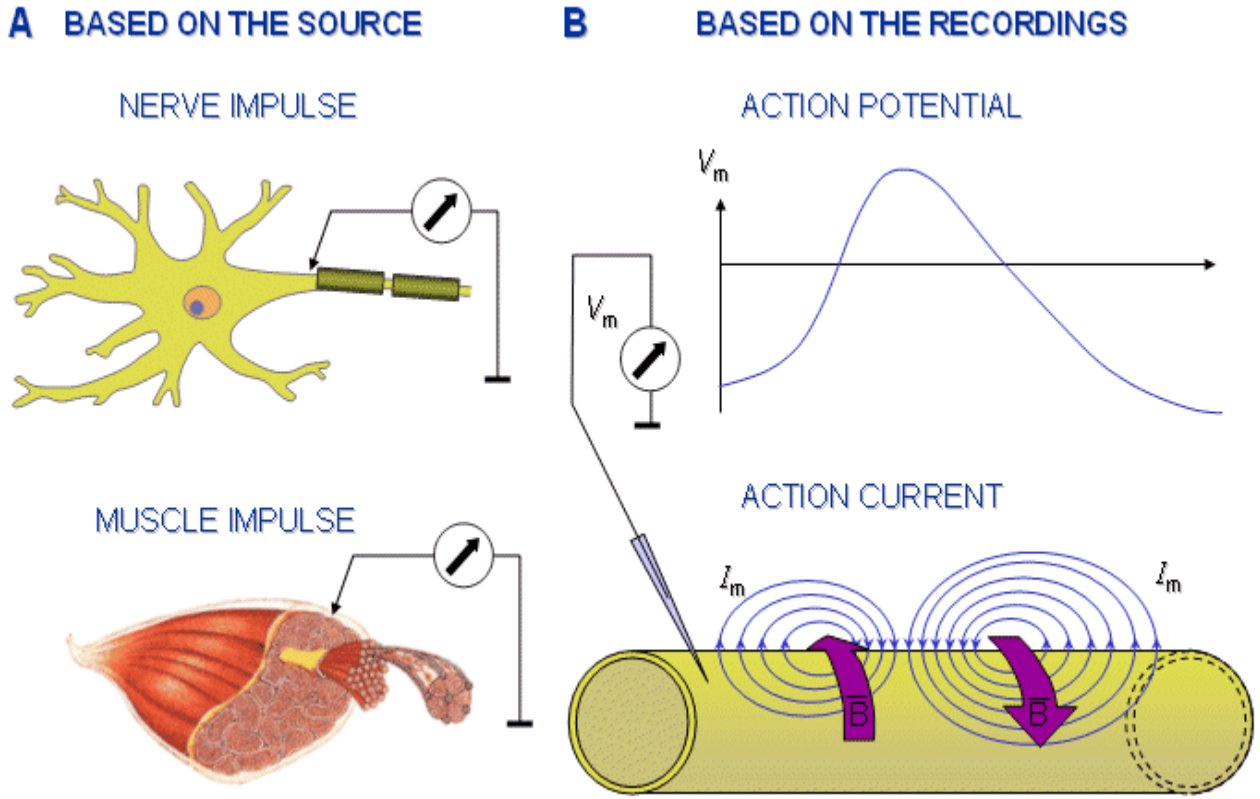
Historical Background

- In 1786, Luigi Galvani found electricity in the muscle of a frog's leg.
- In 19th century other scientists found same effect in animals and man.
- 1903, William Einthoven introduced the string galvanometer, and measured these potentials.

What are biopotentials

Biopotential: An electric potential that is measured between points in living cells, tissues, and organisms, and which accompanies all biochemical processes.

- Also describes the transfer of information between and within cells



Biopotential

Definition:

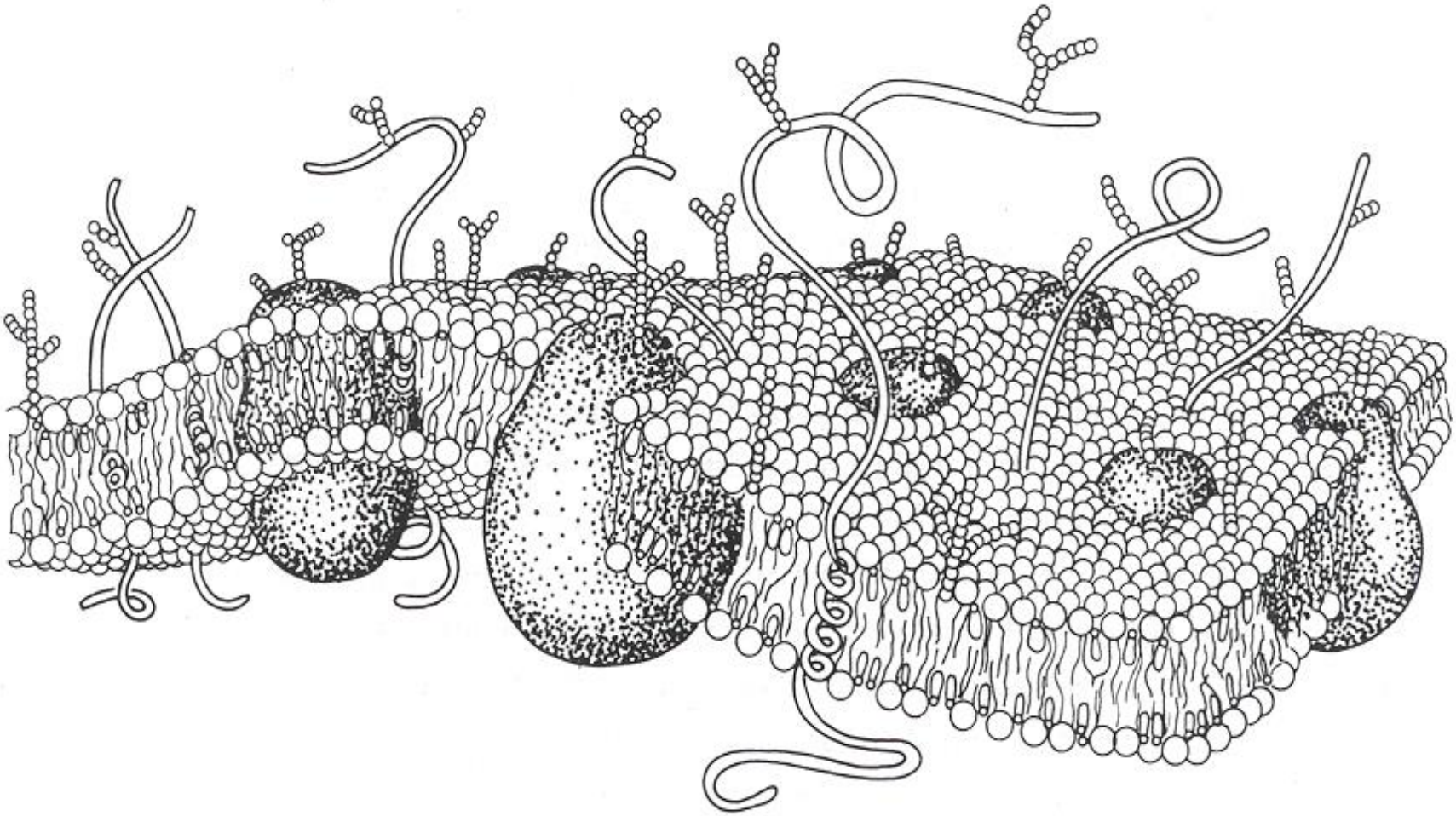
- Ionic voltages produced as a result of the electrochemical activity of *excitable cells.*

Measurement:

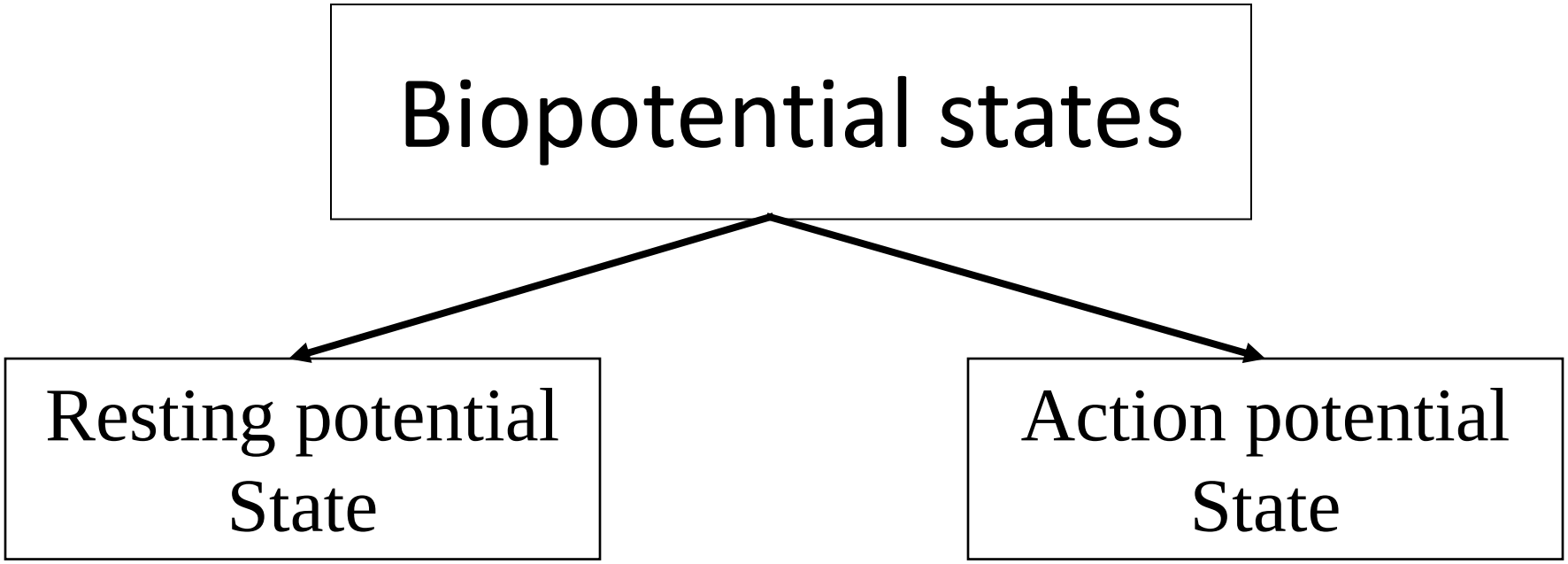
- Using transducers to convert ionic potentials into electrical potentials

The Membrane

- The **membrane** surrounds the neuron.
- It is composed of **lipid** and **protein**.

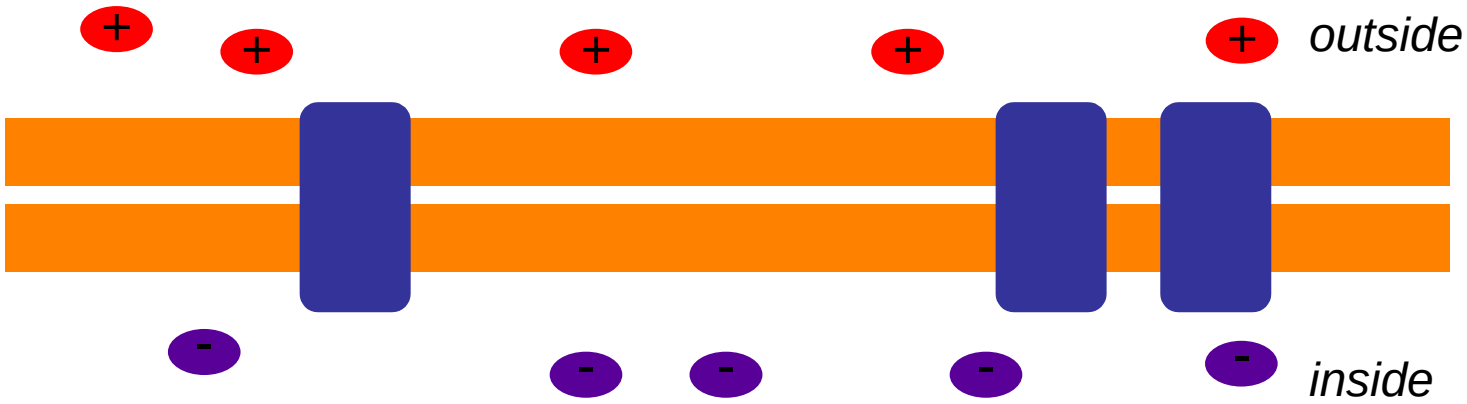


Artist’s rendition of a typical cell membrane


Biopotential states
Resting potential State
Action potential State

The Resting Potential

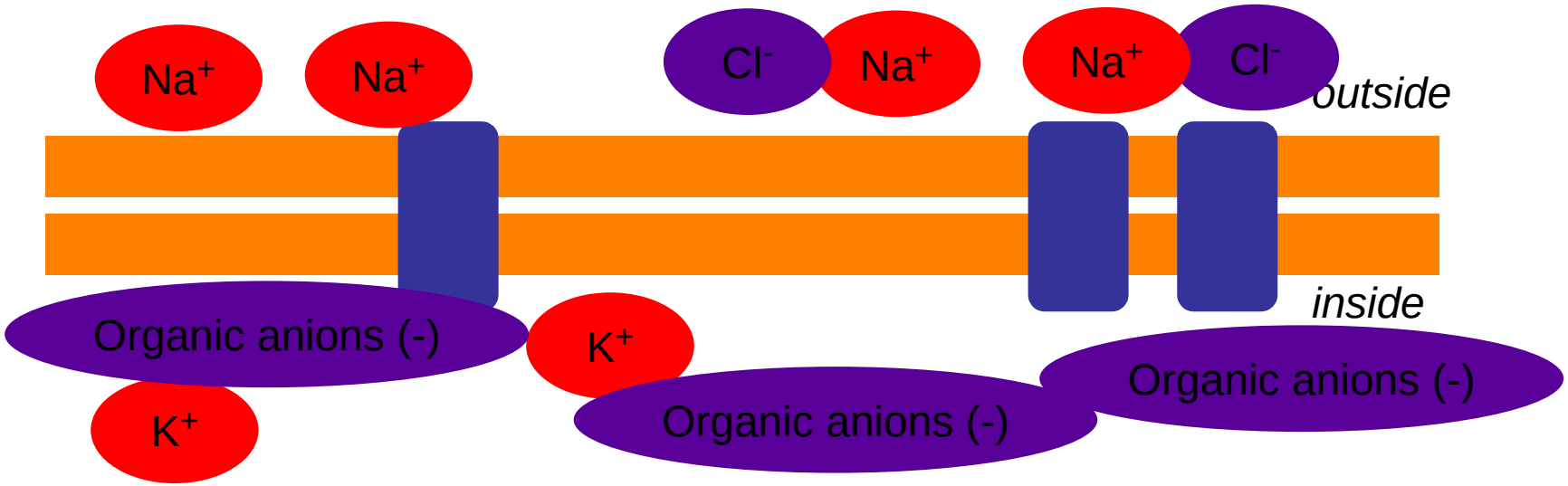
- There is an **electrical charge** across the membrane.
- This is the **membrane potential**.
- The **resting potential** (when the cell is not firing) is a -70mV difference between the inside and the outside.



Resting potential of neuron = -70mV

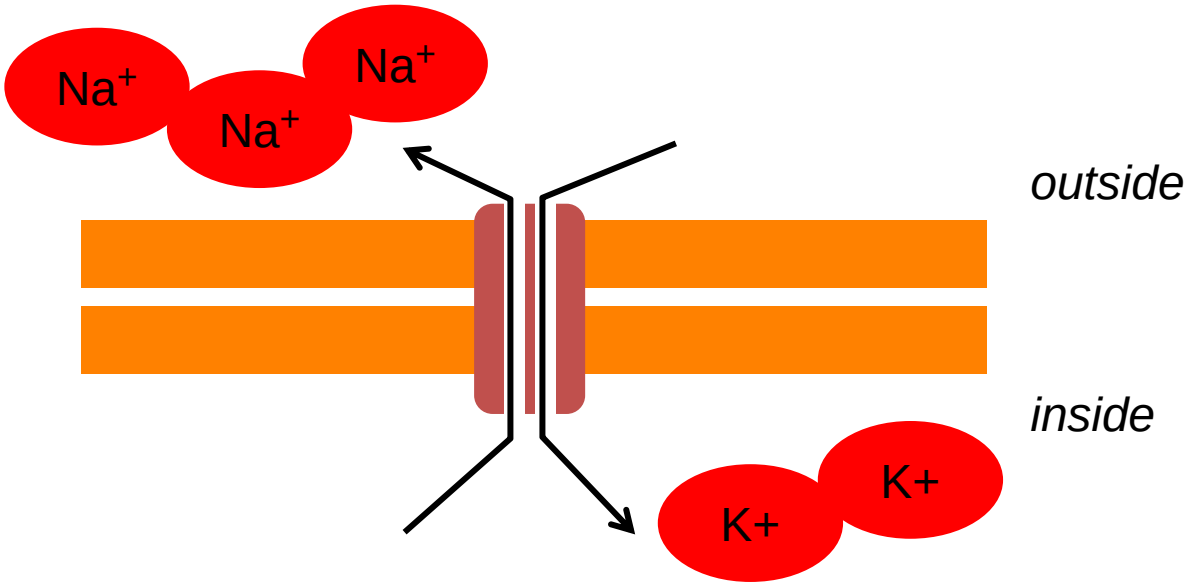
Ions and the Resting Potential

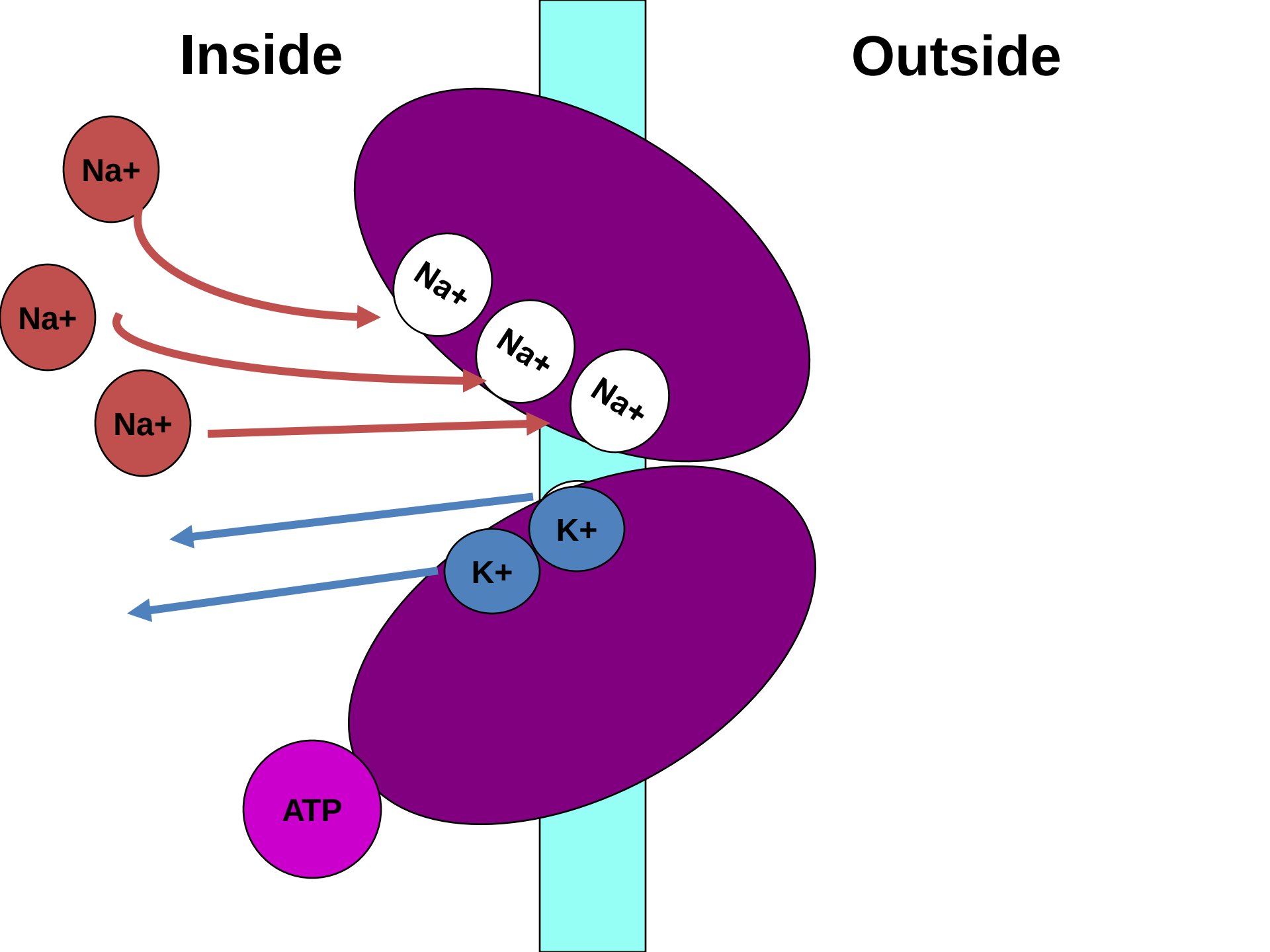
- Ions are **electrically-charged molecules** e.g. sodium (Na+), potassium (K+), chloride (Cl-).
- The resting potential exists because **ions** are **concentrated** on different sides of the membrane.
  - **Na^+** and **Cl^-** outside the cell.
  - **K^+** and **organic anions** inside the cell.

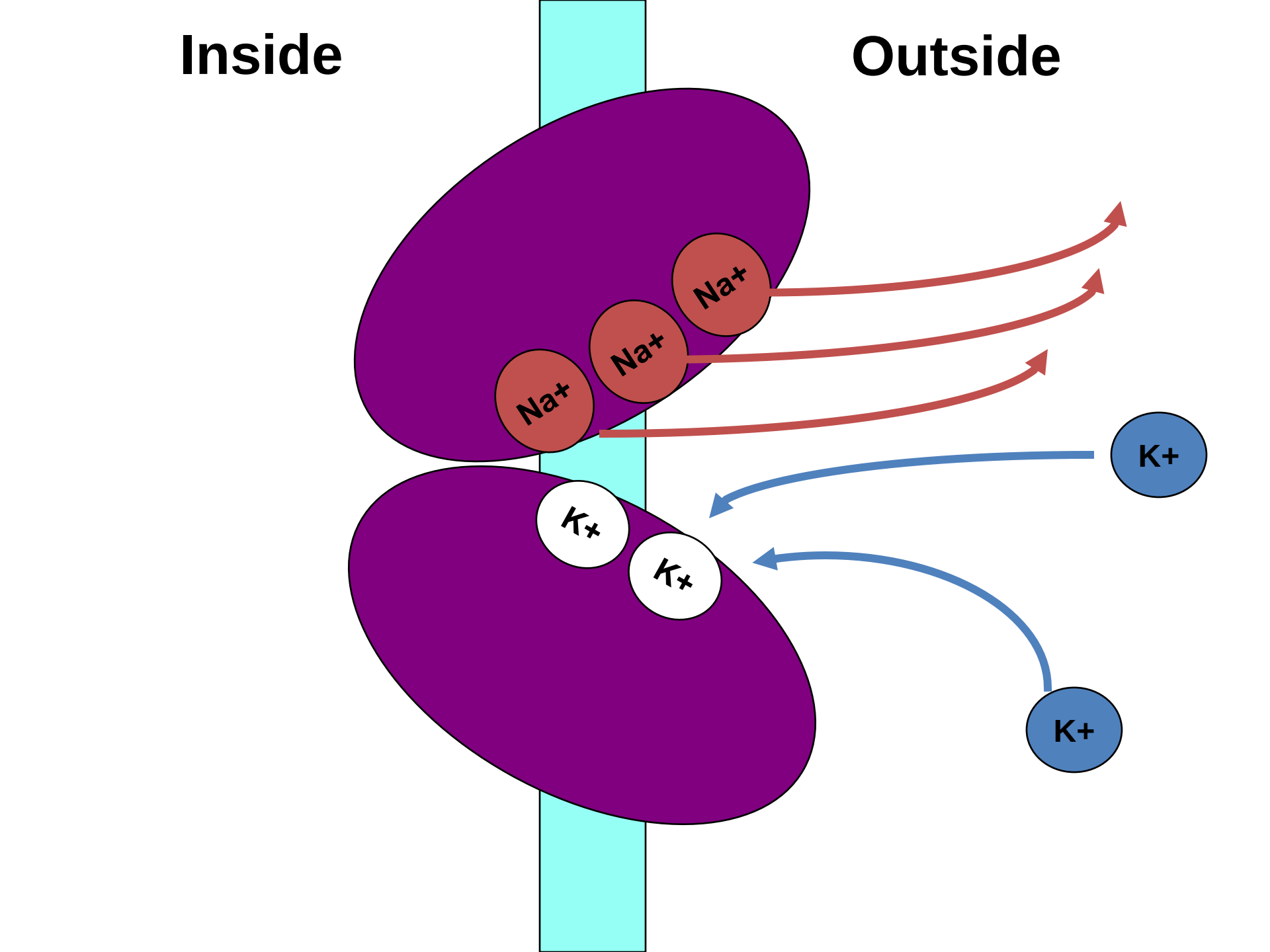


Maintaining the Resting Potential

- Na+ ions are **actively transported** (this uses energy) to maintain the resting potential.
- The **sodium-potassium pump** (a membrane protein) exchanges three Na^+ ions for two K^+ ions.




Inside
Outside
Na+
Na+
Na+
Na+
Na+
Na+
K+
K+
ATP

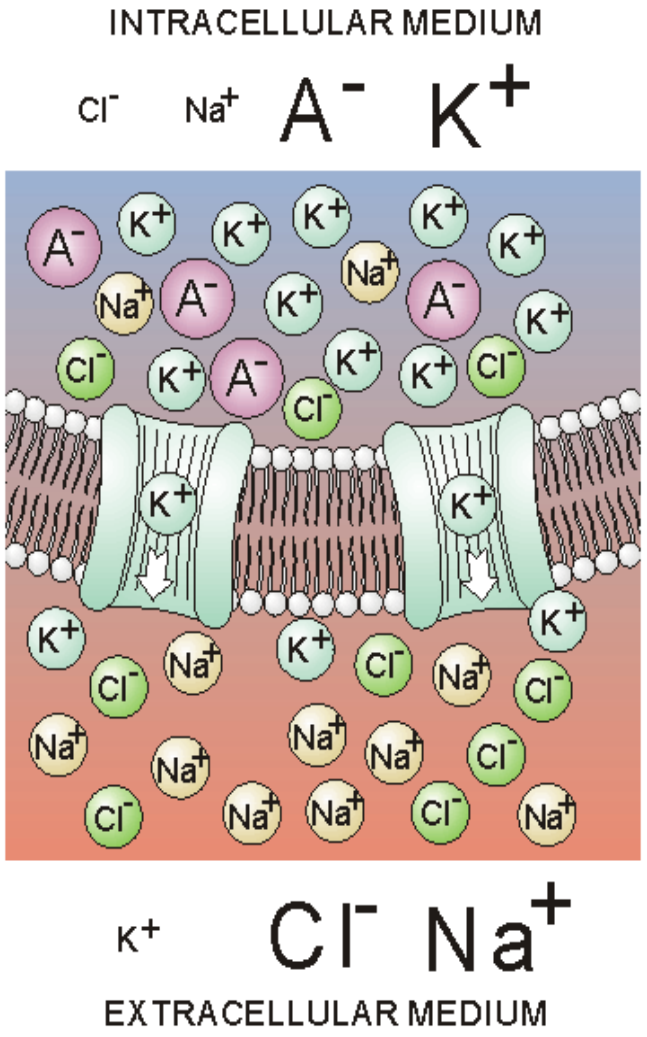

Inside
Outside
Na+
Na+
Na+
K+
K+
K+
K+

Experiments on the neurone of a giant squid

Ion	Concentration /mmol kg^{-1} water		
	Axoplasm (the cytoplasm in an axon)	**Blood plasma**	**Sea water**
K^+	**400**	**20**	**10**
Na^+	**50**	**440**	**460**
Cl^-	120	560	540
Organic anions (-ve ions)	360	-	-

- **Nernst equation:** Used to determine resting membrane potential

$$V_k = -\frac{RT}{z_k F} \ln \frac{c_{i,k}}{c_{o,k}}$$



$$V_m \approx -70 \ldots -100\, mV$$

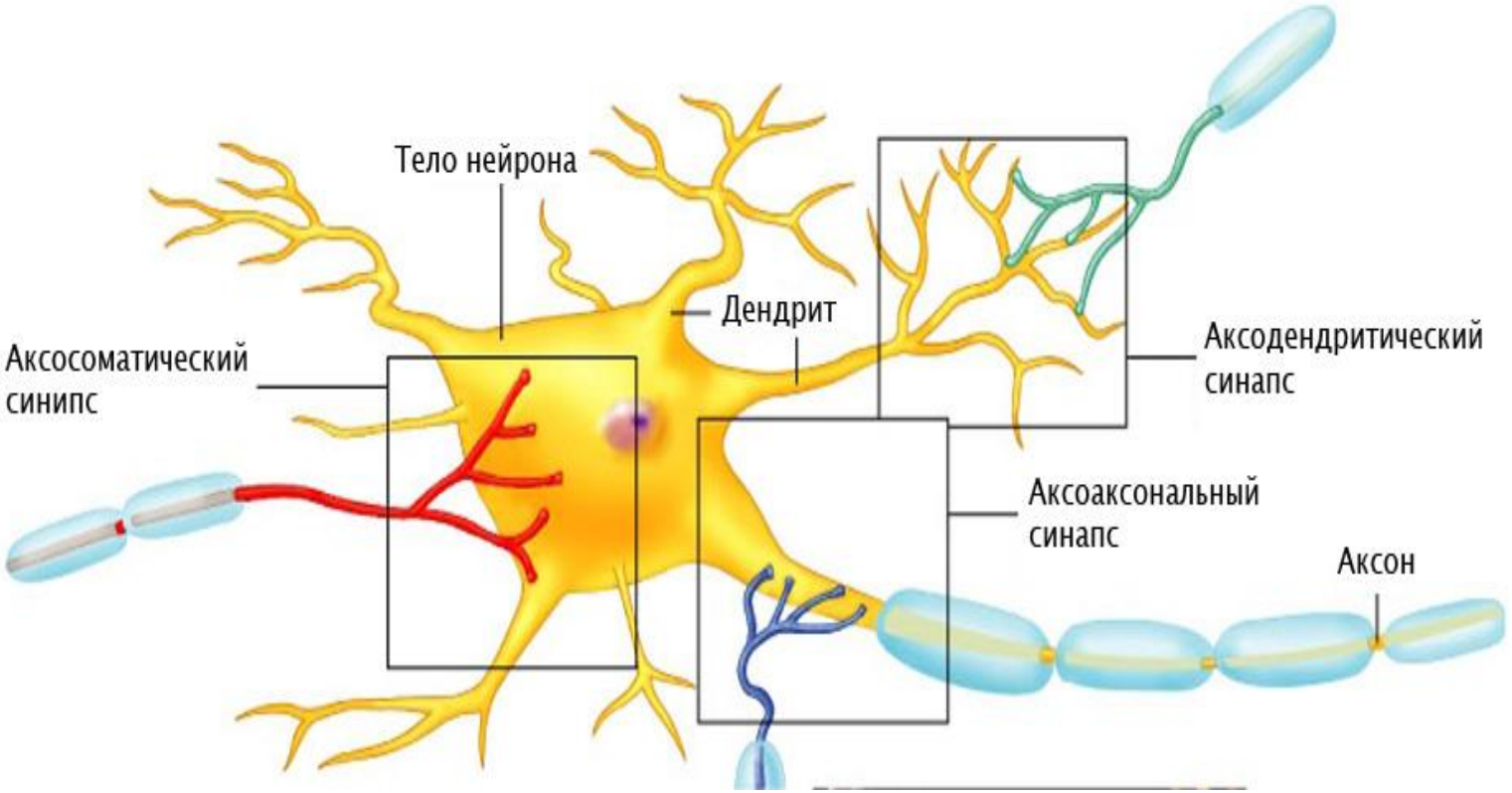
Resting Potential Equation

$$E_{Na} = \frac{RT}{F} \ln \left\{ \frac{Na_O}{Na_I} \right\} \quad = + 60 \text{ mv}$$

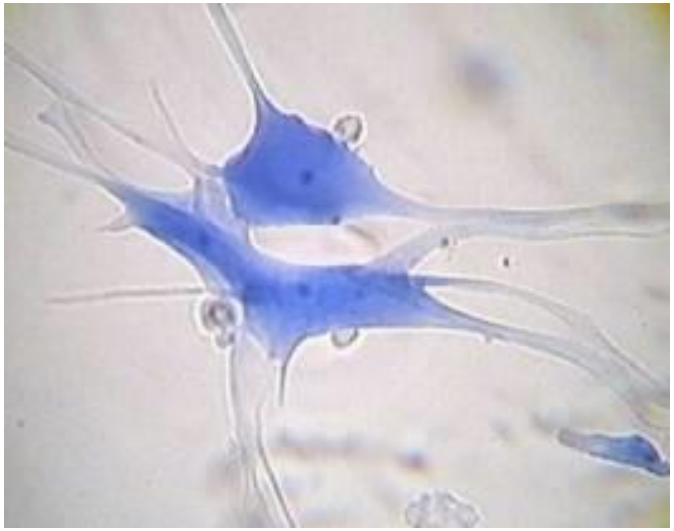
$$E_{K} = \frac{RT}{F} \ln \left\{ \frac{K_O}{K_I} \right\} \quad = -85 \text{ mv}$$

$$E_{Cl} = \frac{RT}{F} \ln \left\{ \frac{Cl_I}{Cl_O} \right\} \quad = -66 \text{ mv}$$

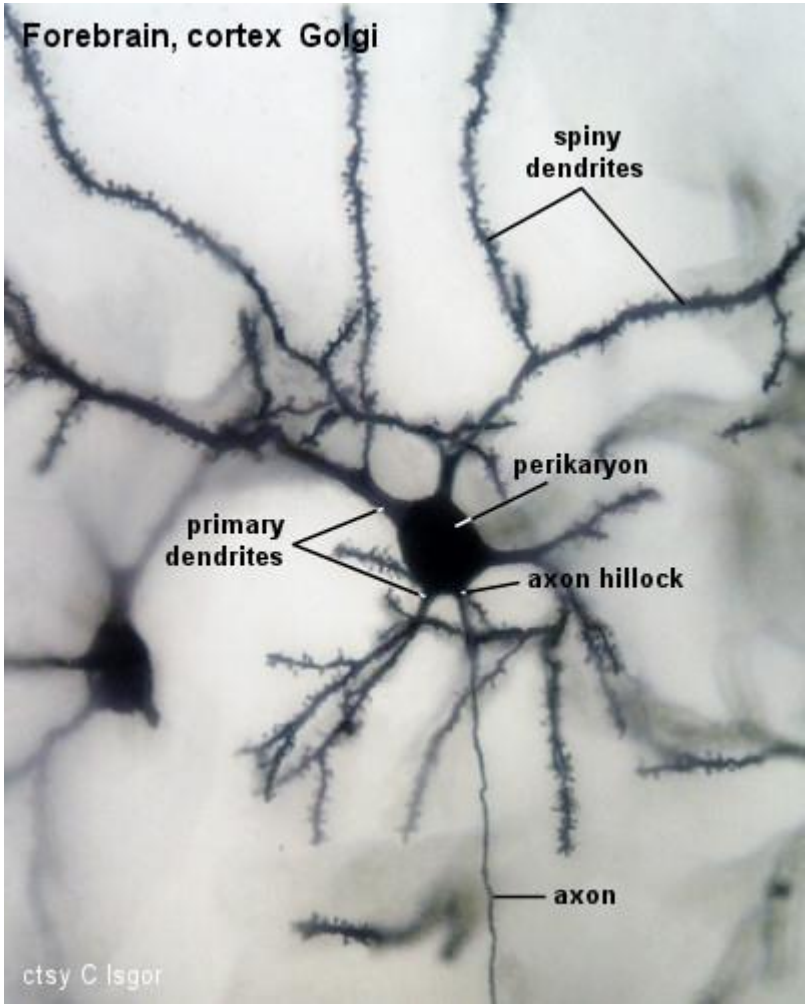
The Action Potential



The neurone

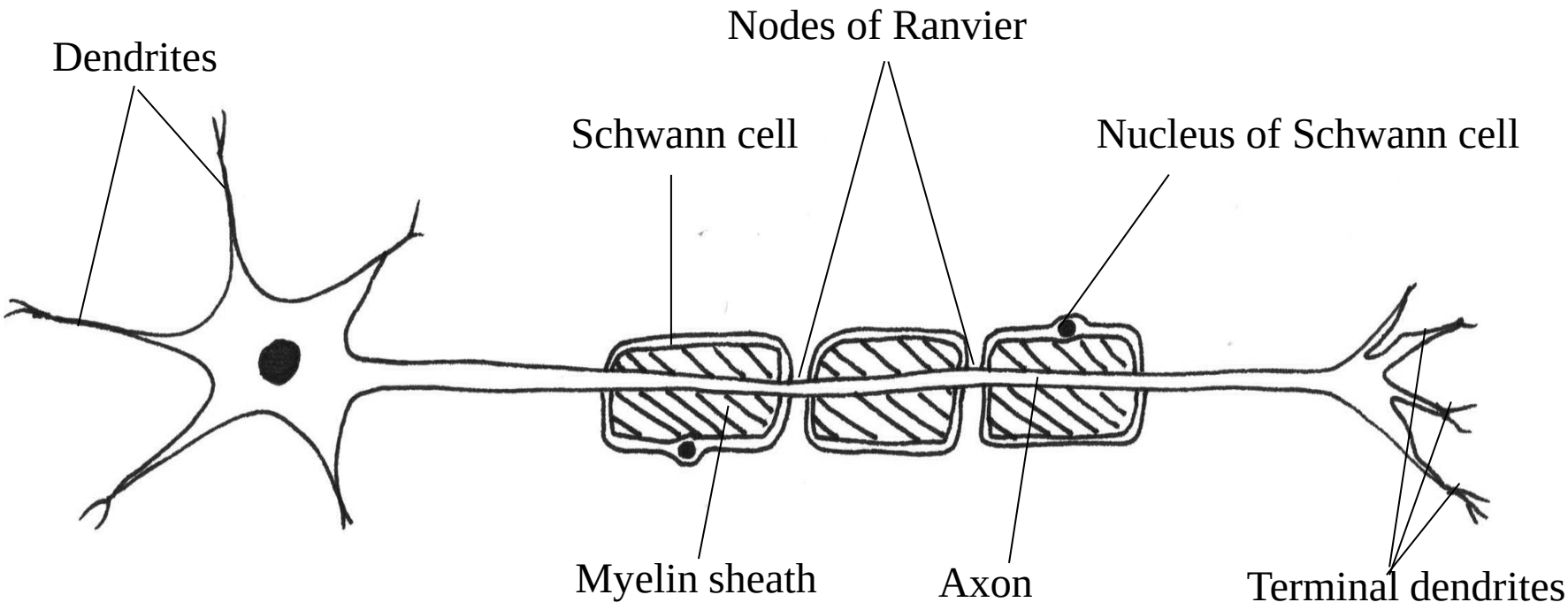


www.biologymad.com



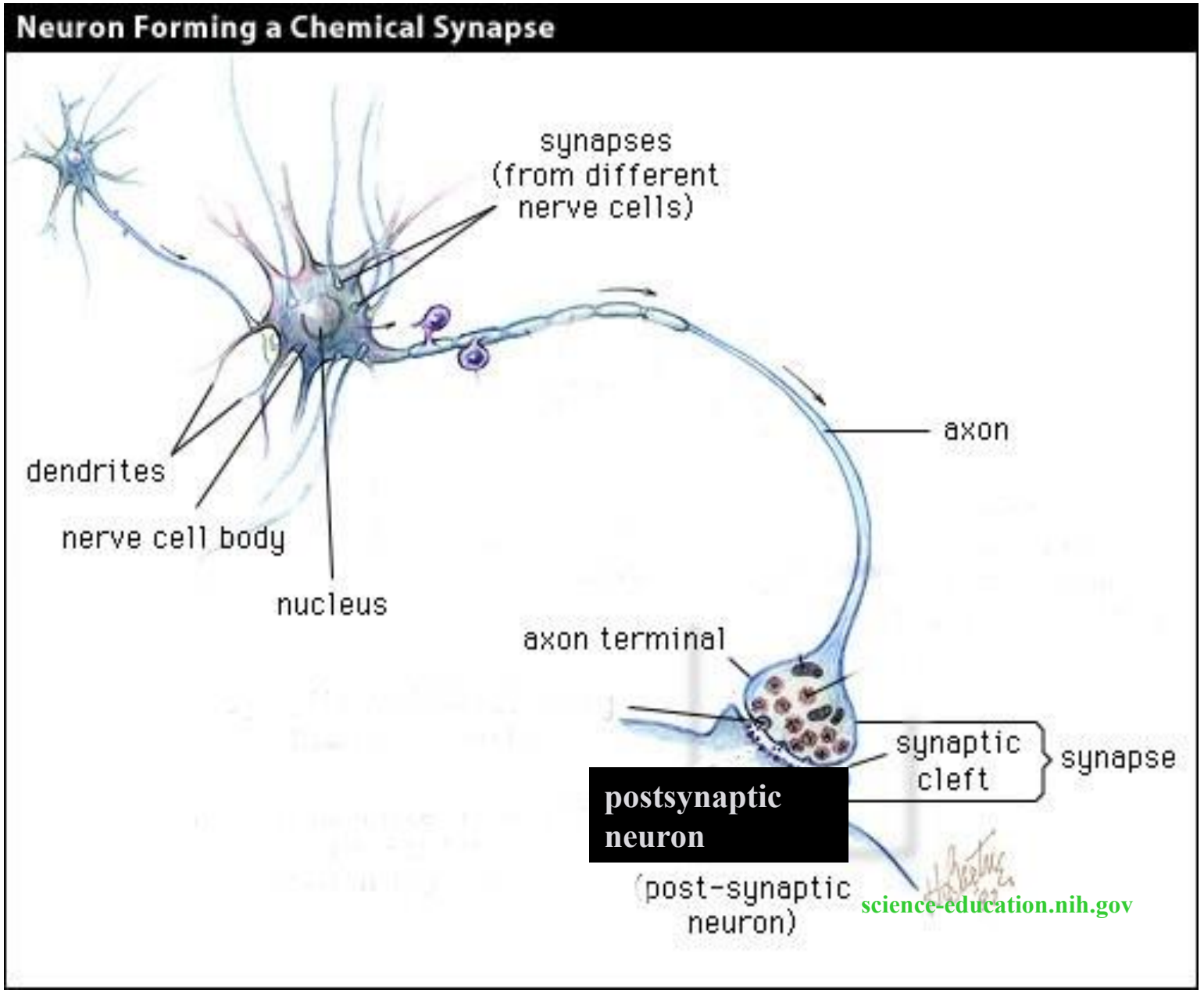
School of Anatomy and Human Biology – The University of Western Australia

The neurone



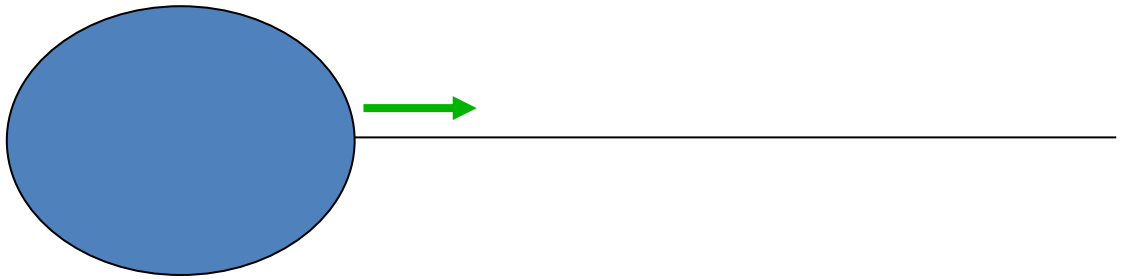
Neurones

- Neurones like other cells are more negatively charged inside than outside
- This results in a **membrane potential** of about – 70 milliVolts
- This is called **the resting potential** of the neurone
- This has an effect on the **passive movement** of K^+ and Na^+ across the neurone's plasma membrane

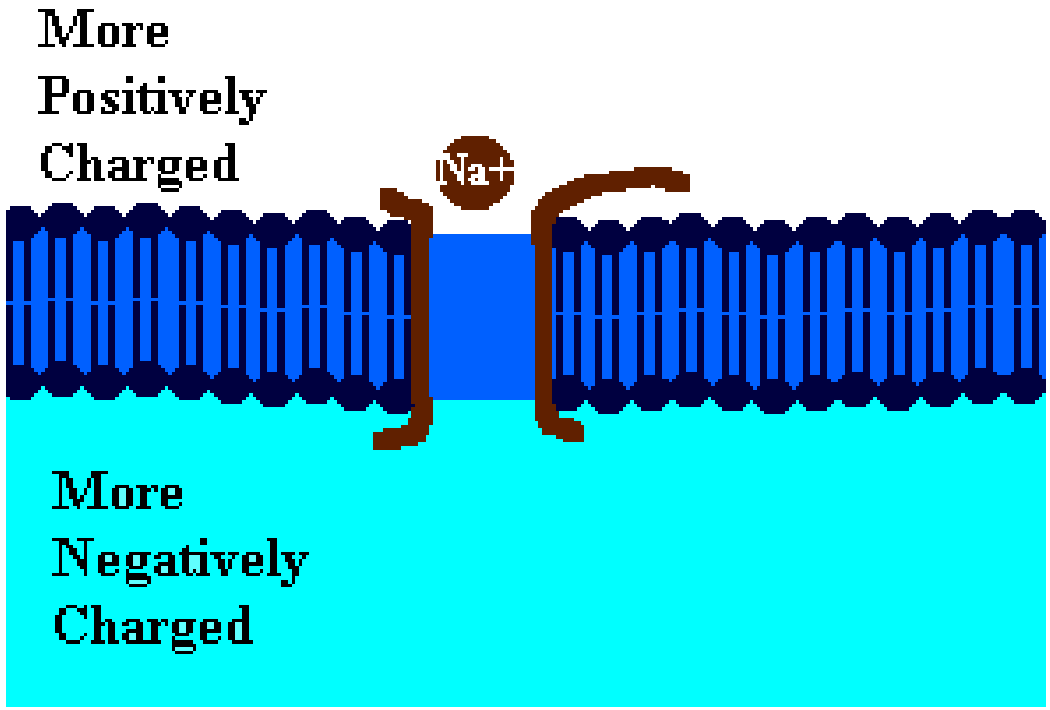

Neuron Forming a Chemical Synapse
synapses
(from different
nerve cells)
axon
dendrites
nerve cell body
nucleus
axon terminal
synaptic
cleft
synapse
postsynaptic
neuron
(post-synaptic
neuron)
science-education.nih.gov

Neuronal firing: the action potential

- The **action potential** is a rapid **depolarization** of the membrane.
- It starts at the **axon hillock** and passes quickly along the **axon**.
- The membrane is quickly **repolarized** to allow subsequent firing.

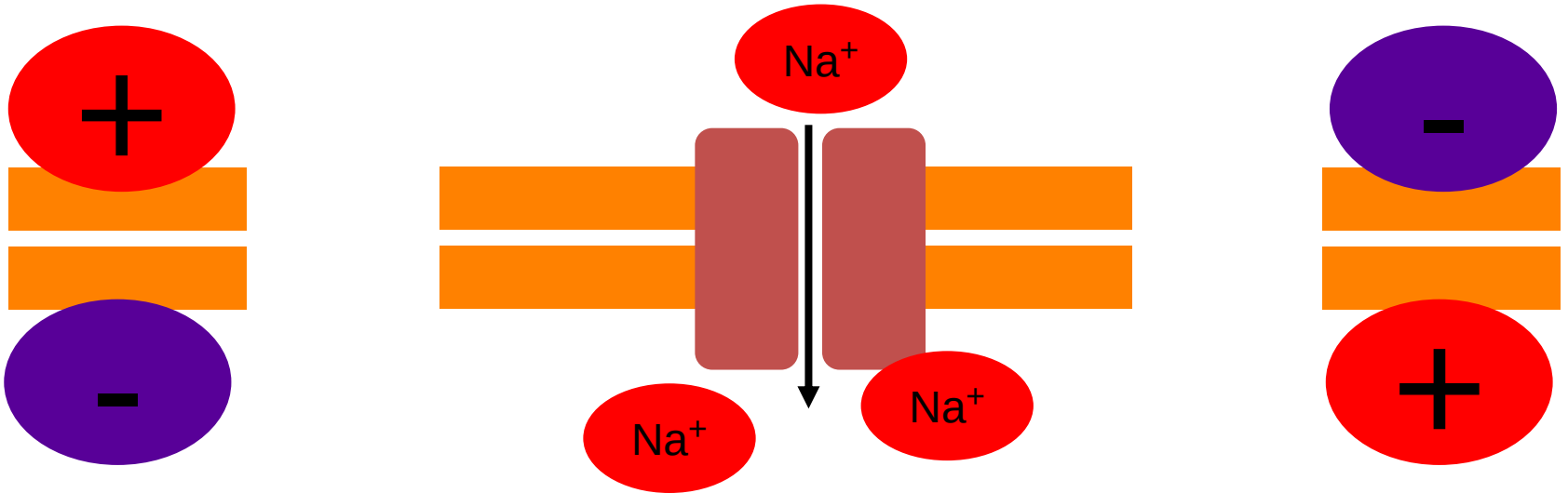


Before Depolarization

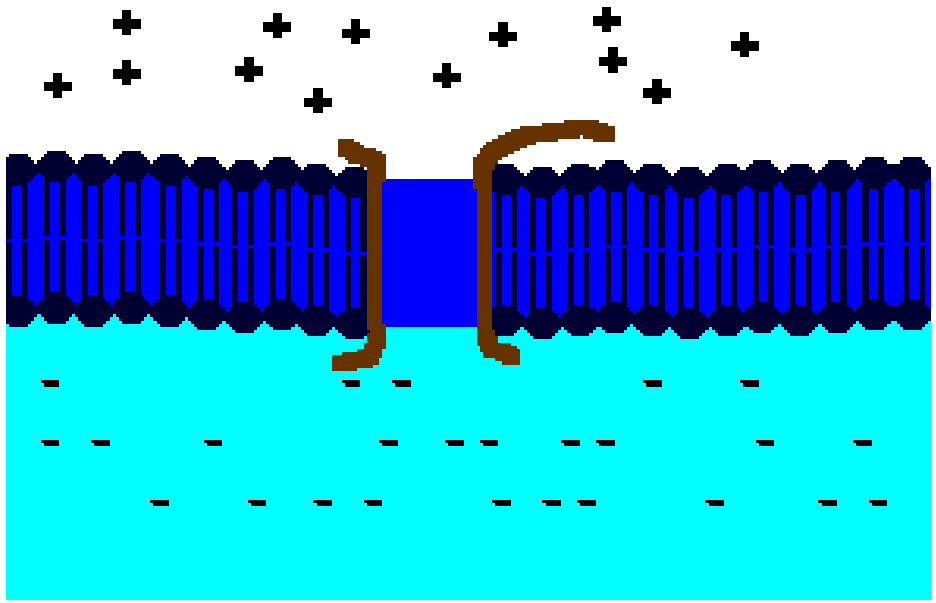


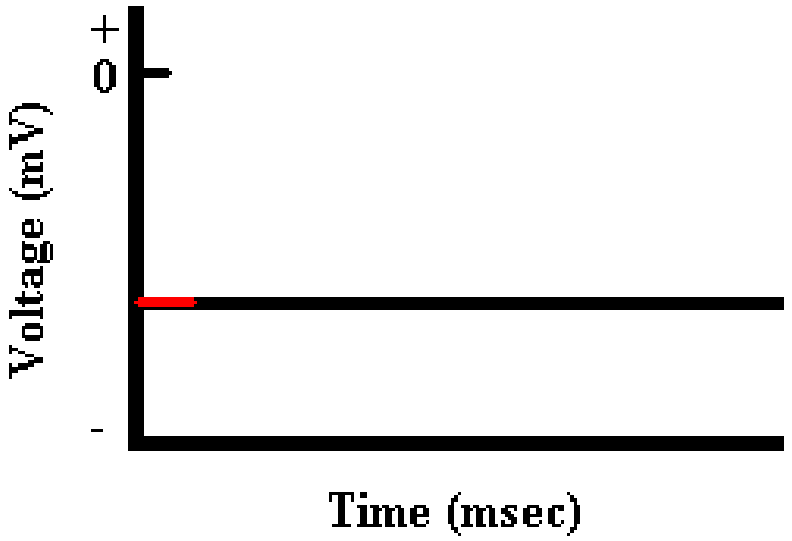
Action potentials: Rapid depolarization

- When partial depolarization reaches the **activation threshold, voltage-gated sodium ion channels** open.
- Sodium ions rush in.
- The membrane potential changes from -70mV to +40mV.



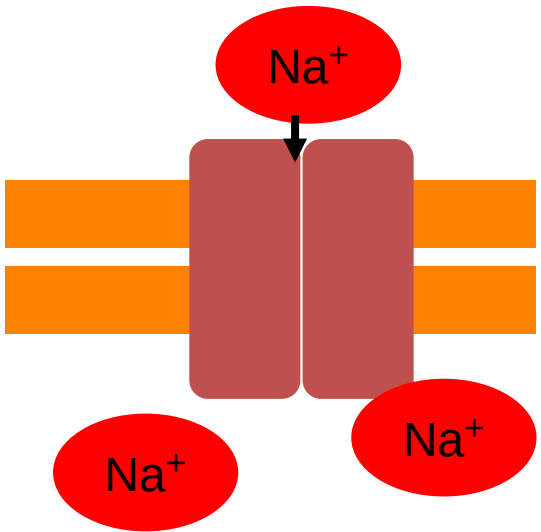
Depolarization

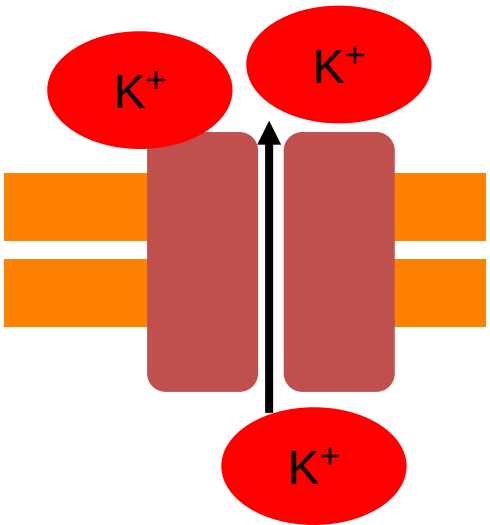


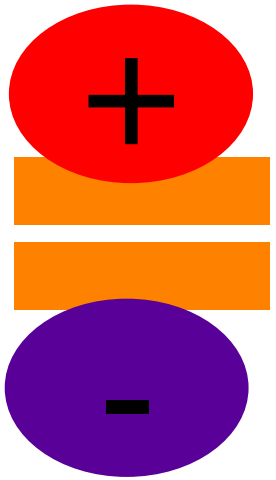


Action potentials: Repolarization

- Sodium ion channels close and become **refractory**.
- Depolarization triggers opening of **voltage-gated potassium ion channels.**
- **K+** ions rush out of the cell, repolarizing and then hyperpolarizing the membrane.





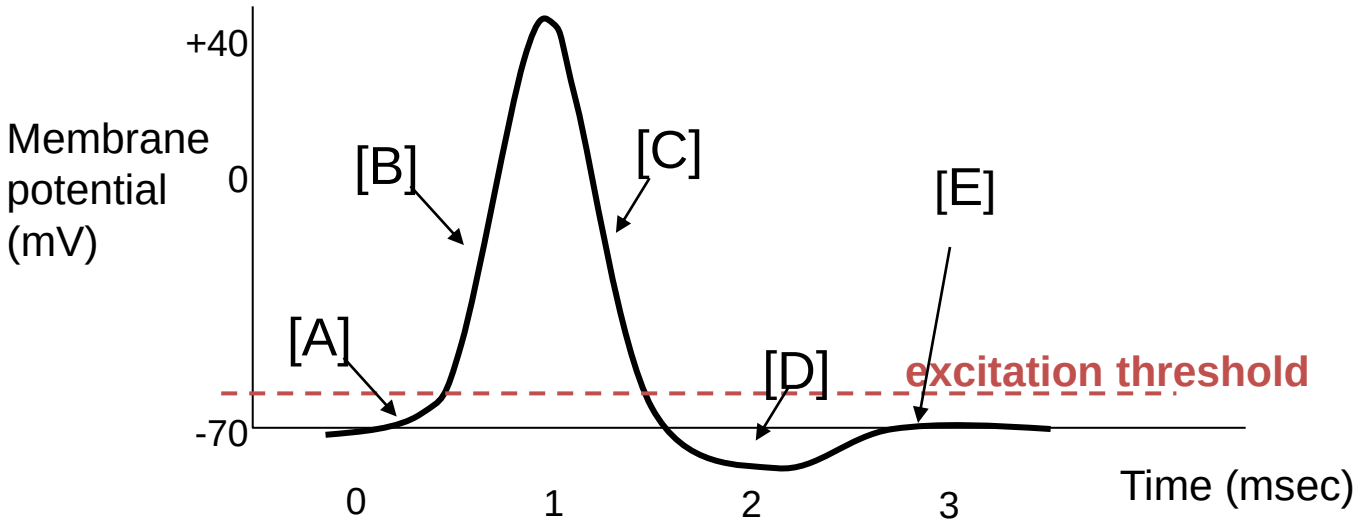


The Action Potential

- The action potential is **“all-or-none”**.
- It is always the same size.
- Either it is not triggered at all - e.g. too little depolarization, or the membrane is “refractory”;
- Or it is triggered completely.

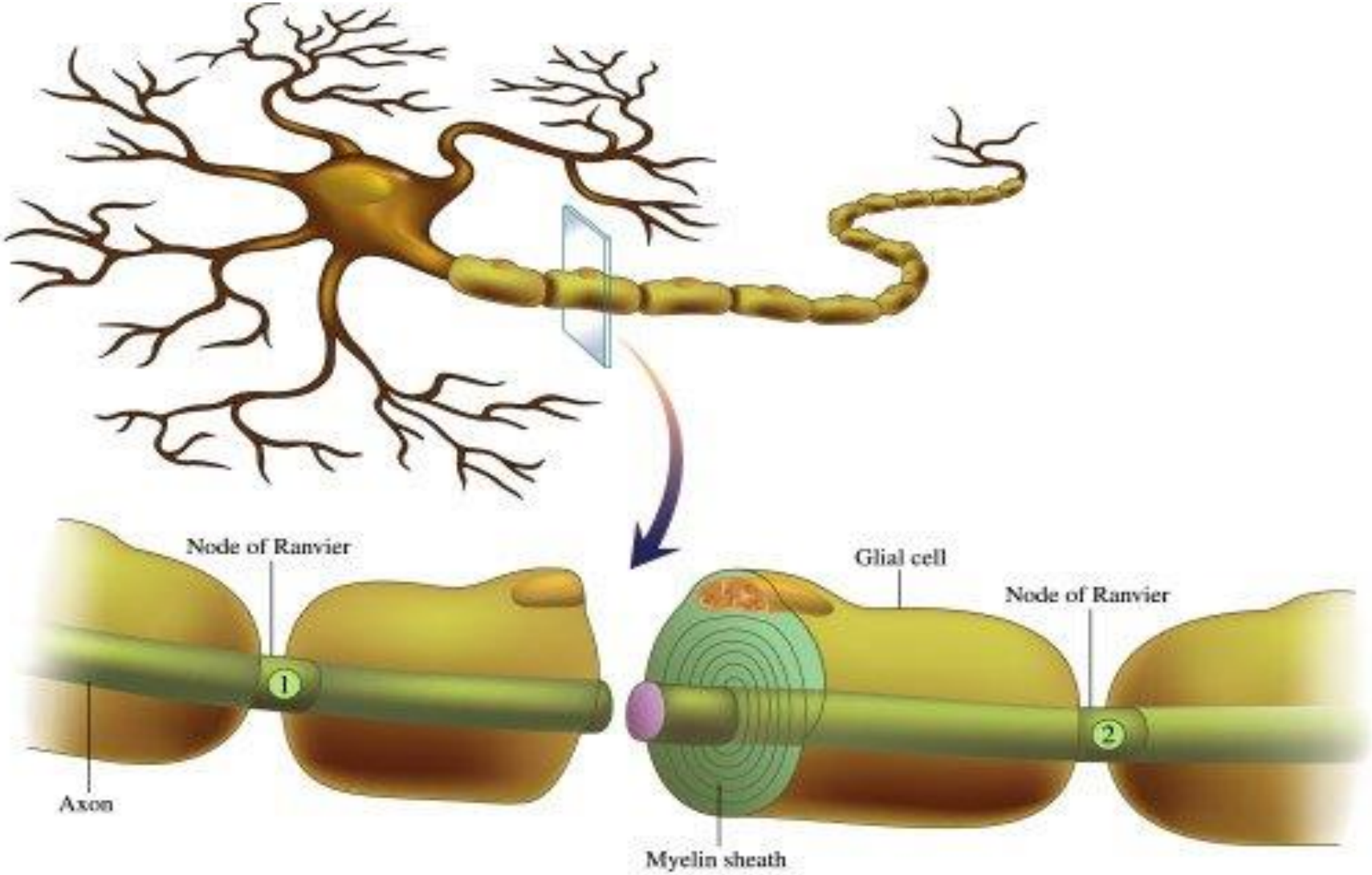
Course of the Action Potential

- The action potential begins with a **partial depolarization** (e.g. from firing of another neuron) [A].
- When the **excitation threshold** is reached there is a sudden large **depolarization** [B].
- This is followed rapidly by **repolarization** [C] and a brief **hyperpolarization** [D].
- There is a **refractory period** immediately after the action potential where no depolarization can occur [E]



Conduction of the action potential.

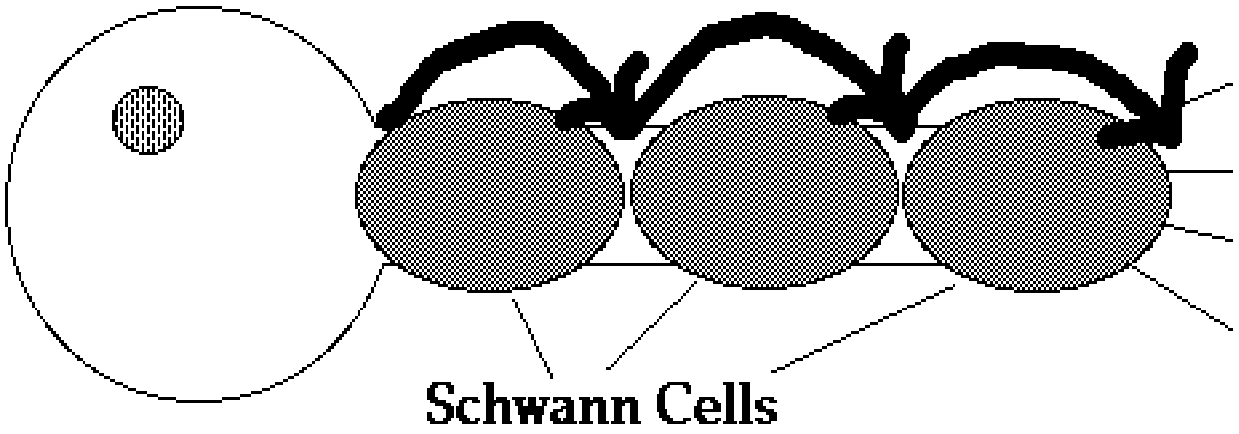
- **Passive conduction** will ensure that adjacent membrane depolarizes, so the action potential "travels" down the axon.
- But transmission by continuous action potentials is relatively **slow** and **energy-consuming** (Na^+/K^+ pump).
- A faster, more efficient mechanism has evolved: **saltatory conduction.**
- **Myelination** provides saltatory conduction.



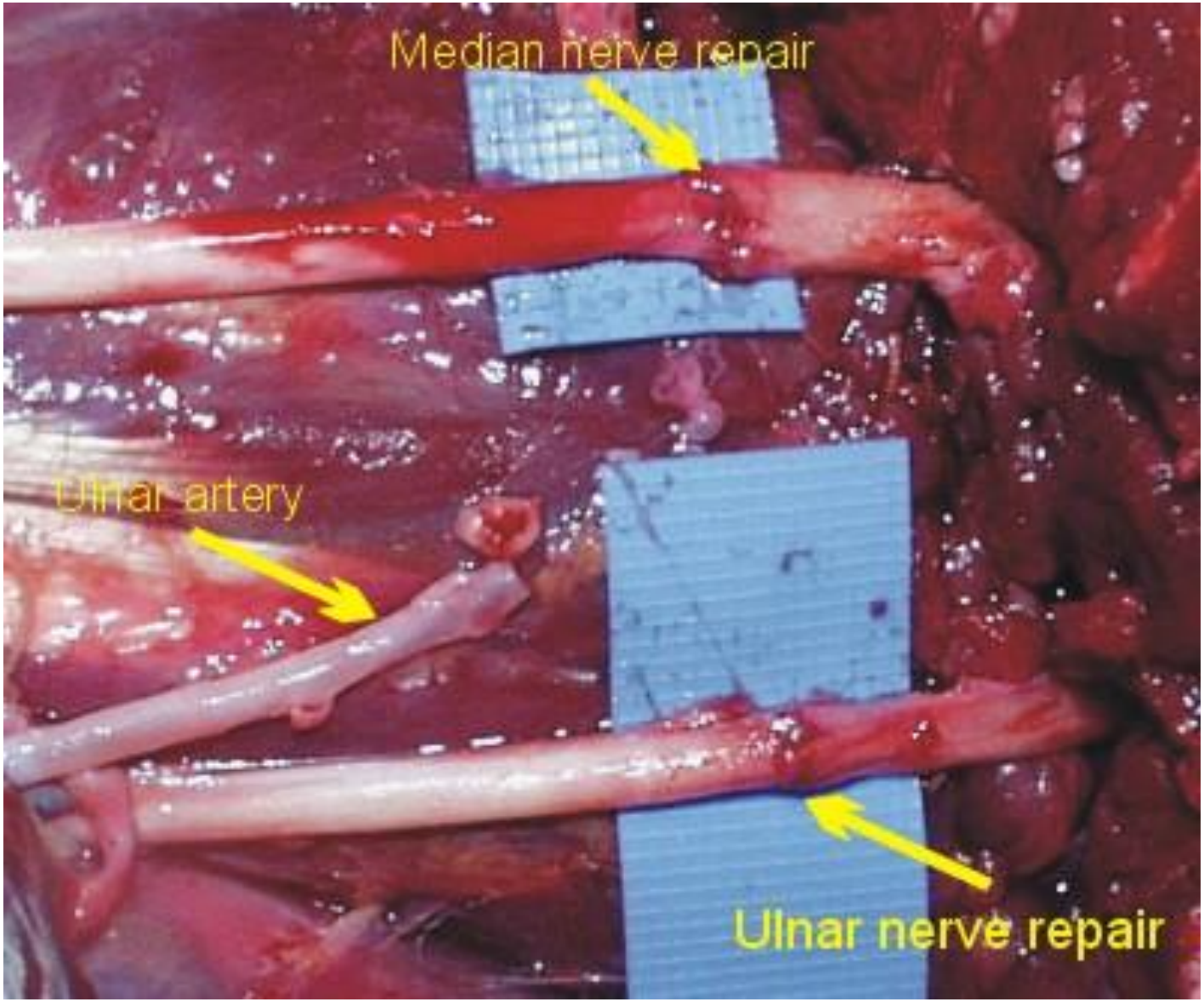
Action potential at node 1 depolarizes node 2

NEUROBIOLOGY
Gary G. Matthews
Blackwell Science

Saltatory Conduction



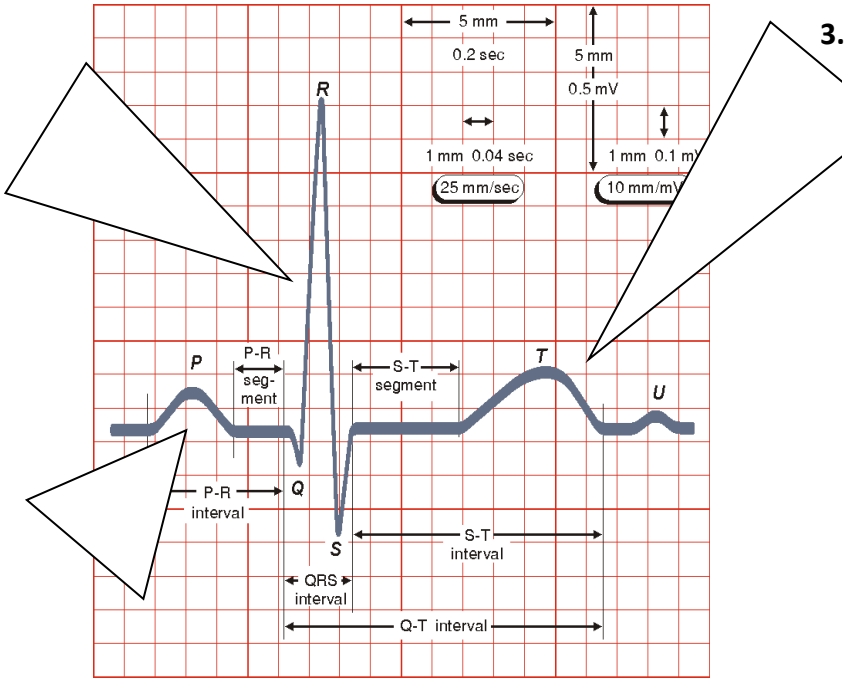
Nerve Impulse jumps from cell to cell


Median nerve repair
Ulnar artery
Ulnar nerve repair

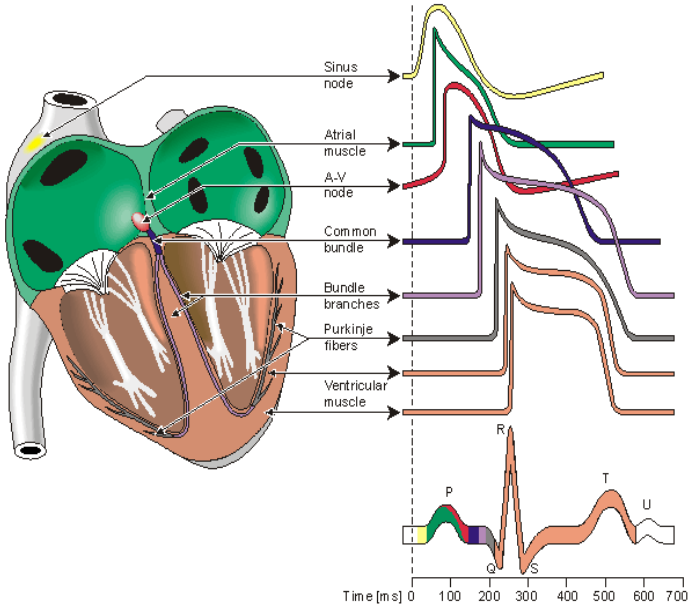
Measurement methods: Electrocardiography (ECG)

- Measures galvanically the electric activity of the heart
- Well known and traditional, first measurements by Augustus Waller using capillary electrometer (year 1887)
- Very widely used method in clinical environment
- Very high diagnostic value

2. Ventricular depolarization



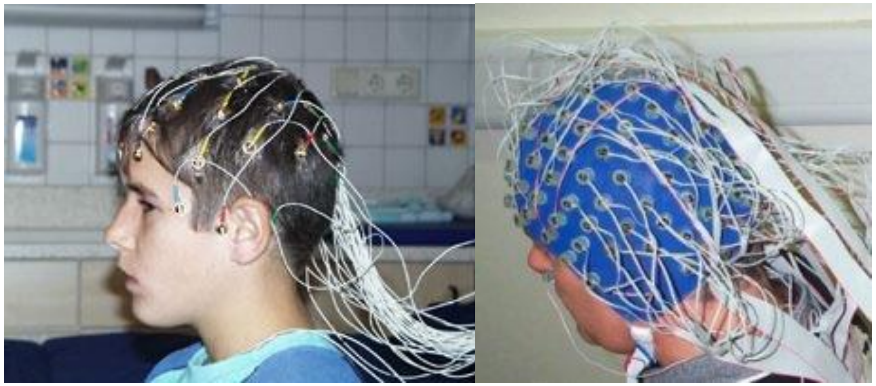
3. Ventricular repolarization

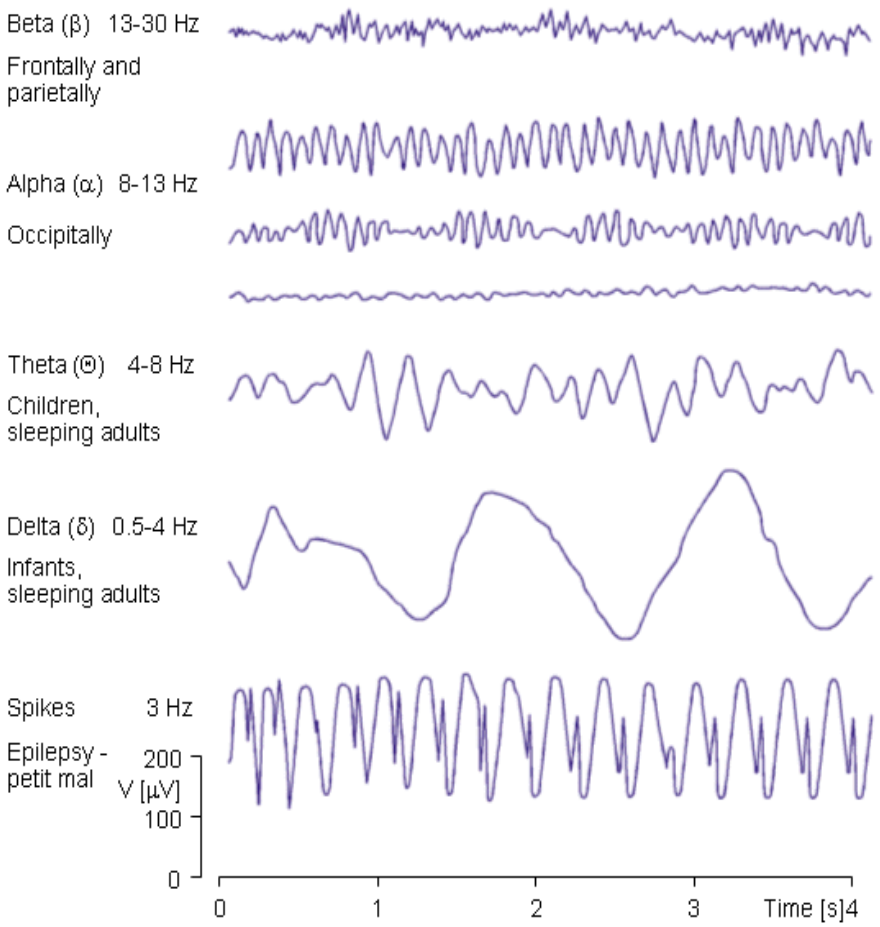


1. Atrial depolarization

Measurement methods: Electroencephalography (EEG)

- Measures the brain's electric activity from the scalp
- Measured signal results from the activity of billions of neurons

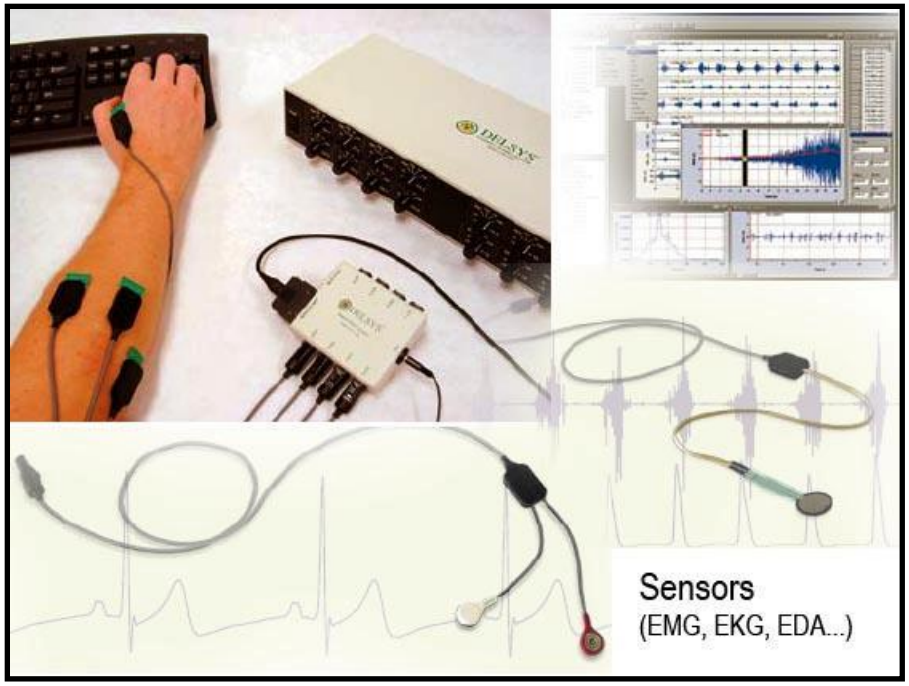




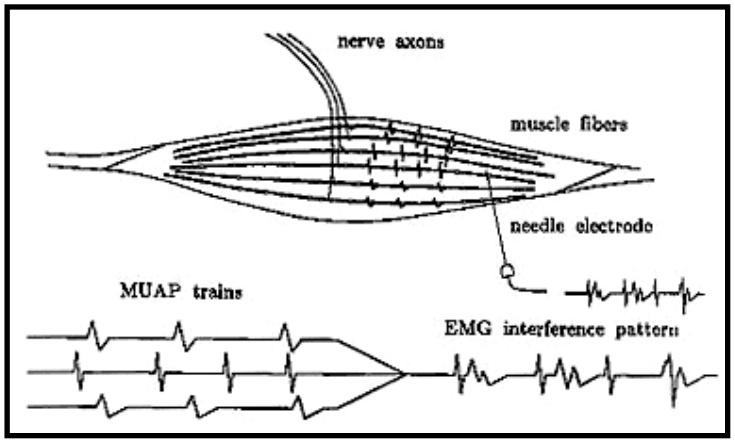
Measurement methods: Electromyography (EMG)

- Electromyogram (EMG) is a technique for evaluating and recording the activation signal of muscles.
- EMG is performed by an **electromyograph**, which records an **electromyogram**.
- Electromyograph detects the electrical potential generated by muscle cells when these cells contract and relax.

Measurement methods: Electromyography (EMG)



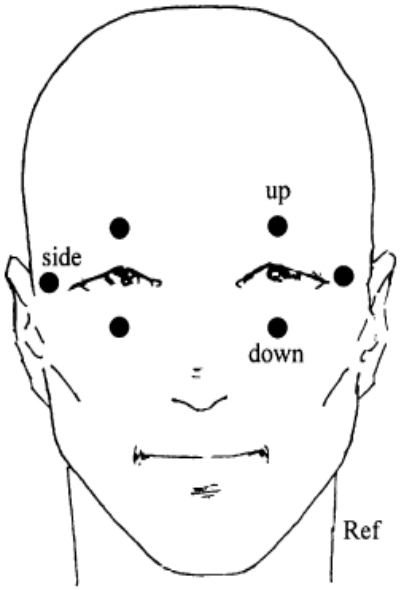
EMG Apparatus



Muscle Structure/EMG

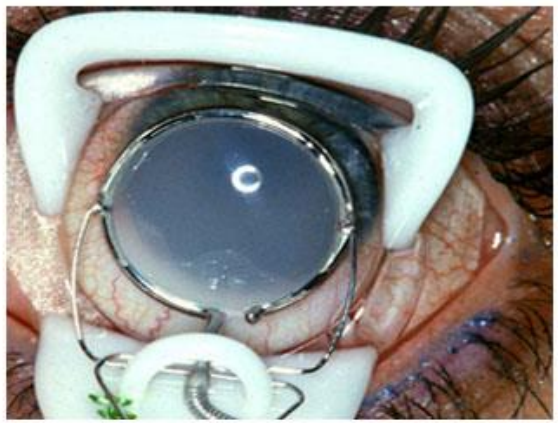
Electrooculography (EOG)

- Electric potentials are created as a result of the movement of the eyeballs
- Potential varies in proportion to the amplitude of the movement
- In many ways a challenging measurement with some clinical value

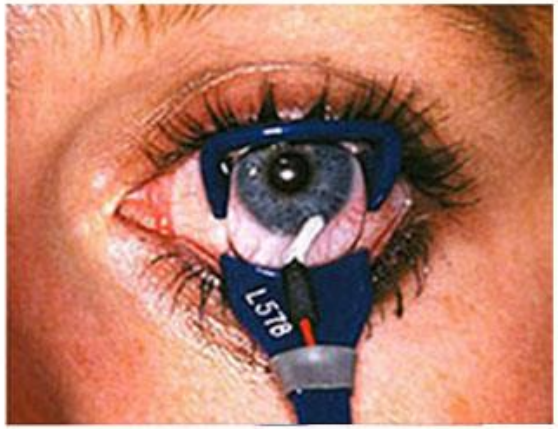


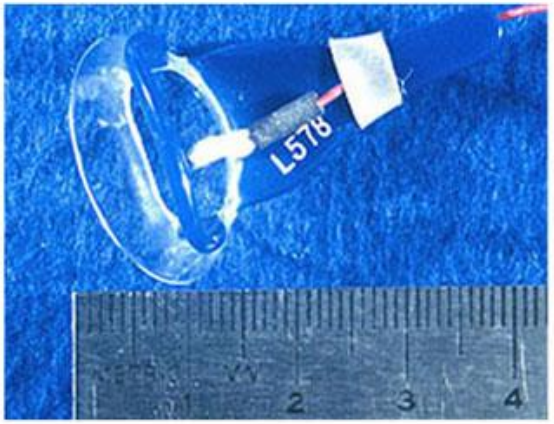
ERG recording electrodes

Burian speculum type electrodes

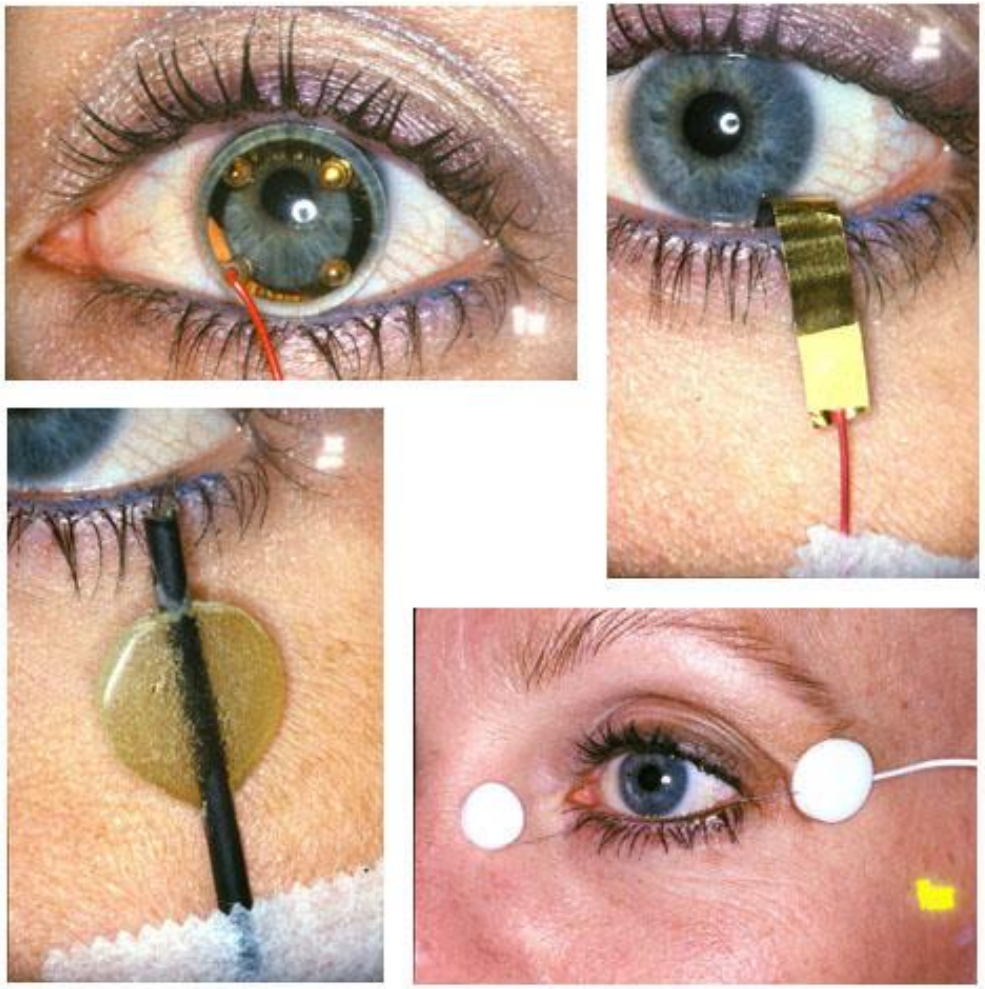


Cotton wick electrodes





ERG recording electrodes



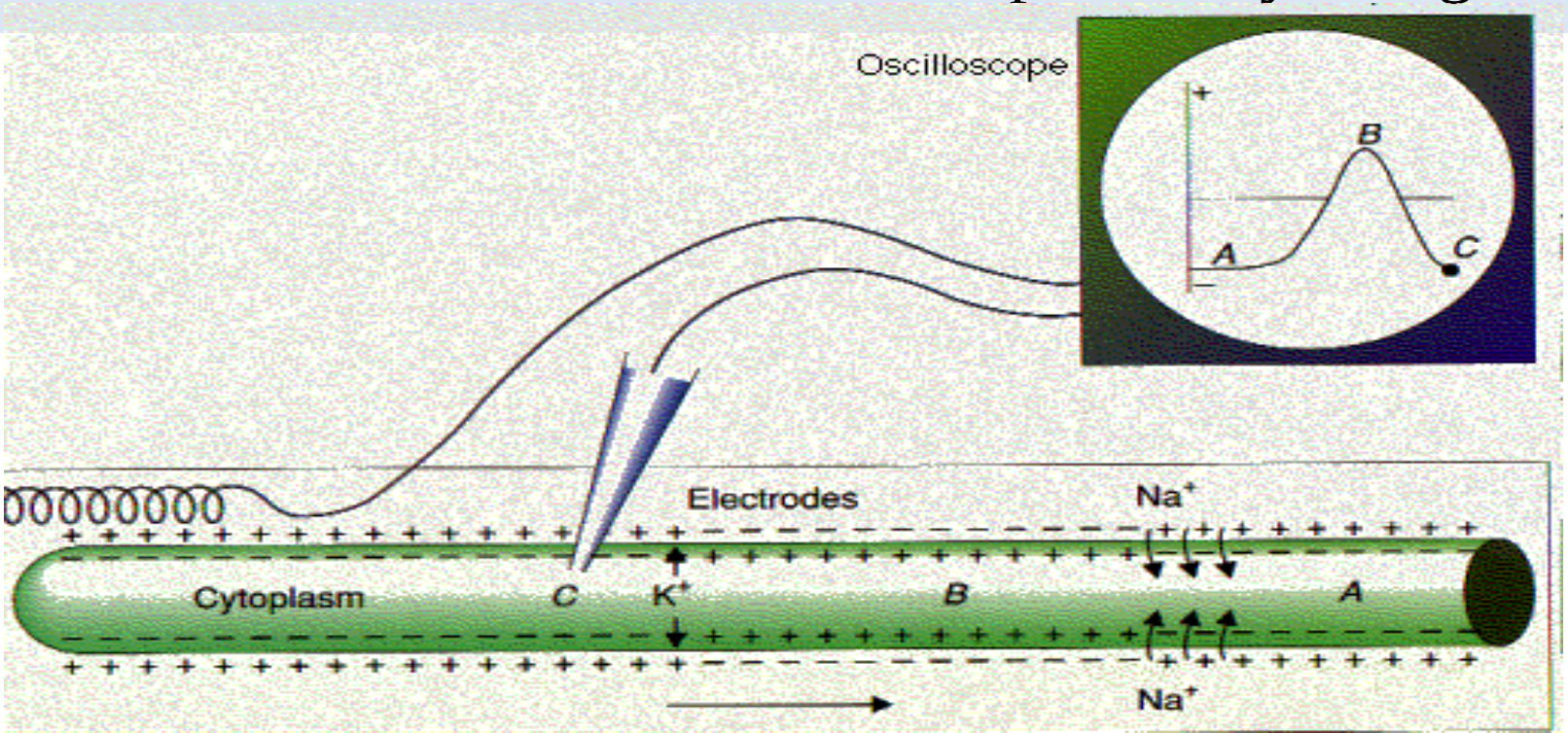
some corneal ERG electrodes


THANK YOU

THE NEUROMUSCULAR (NERVE-MUSCLE) CONNECTION

MUSCLE CONTRACTION

- **The action potential** - excitation wave that moves on the membrane of living cells in the form of short-term changes in membrane potential in a small region of the excitable cells (neuron or cardiomyocytes), resulting in the outer surface of this portion becomes negatively charged with respect to the inner surface of the membrane, while alone it is positively charged.



- Due to the "sodium-potassium pump" the concentration of sodium ions in the cytoplasm of cells is very small compared with the environment.
- During the action potential, open voltage-gated sodium channels and positively charged sodium ions enter the cytoplasm of the concentration gradient, until it is balanced by a positive electric charge.
- Following this, the potential-dependent channels are inactivated and the negative resting potential is reduced due to diffusion of cells positively charged potassium ions, whose concentration in the environment is also significantly lower intracellular.

What are the muscles?

Movement is a fundamental characteristic of all living organisms, from bacteria to humans.

The evolution brought us to the **muscle cells** specialized for this function.

A muscle cell is essentially a device for converting the chemical energy of ATP into the mechanical energy of movement.

Across the entire spectrum of life, the molecular mechanisms of movement are very similar, involving motor proteins such as myosin and dynein.

3 types

- skeletal or striated

Under direct (Voluntary) nervous control

- cardiac

Striated but specialised and confined to the heart

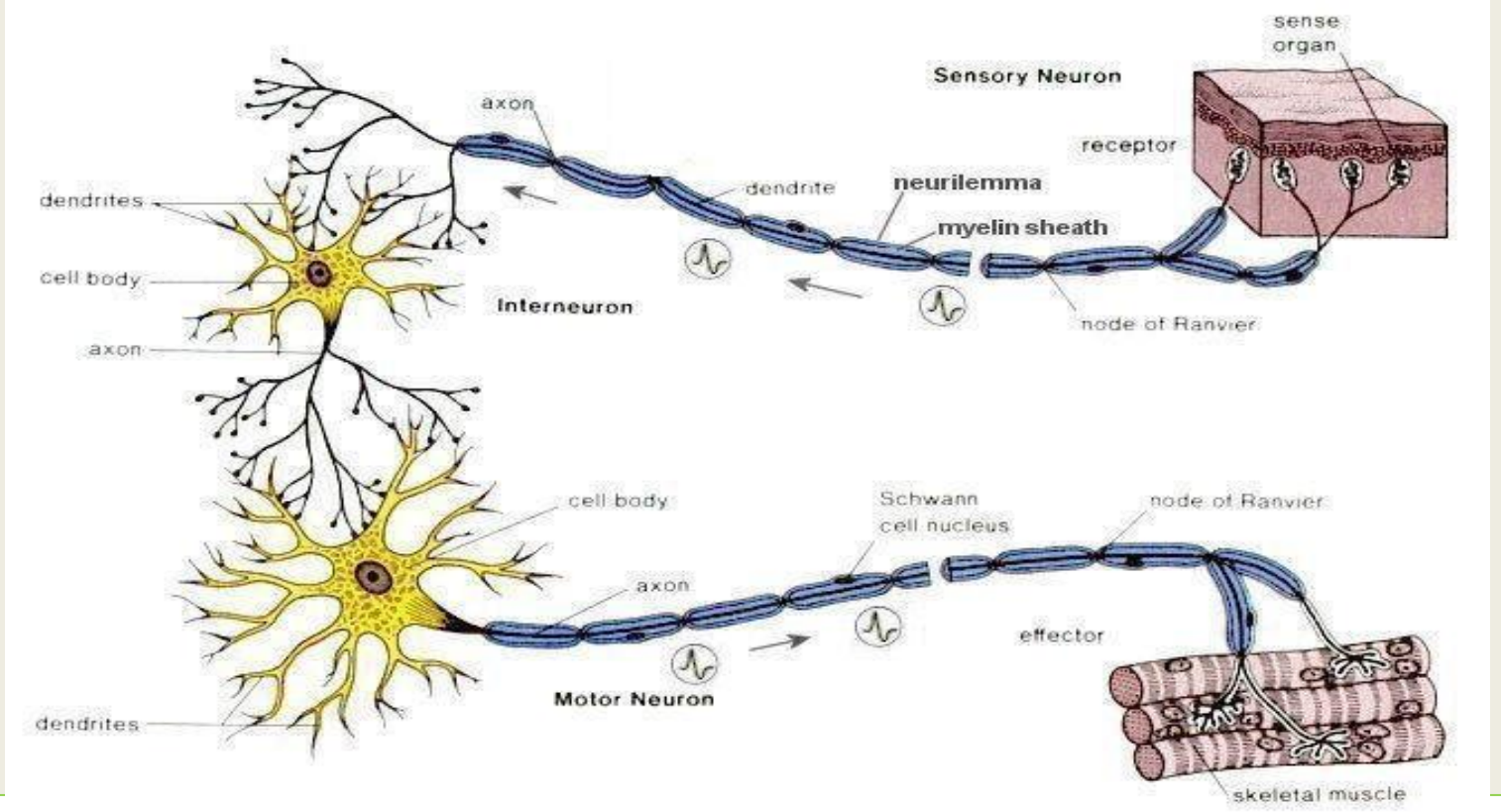
- smooth or visceral

Not under direct (voluntary) nervous control.

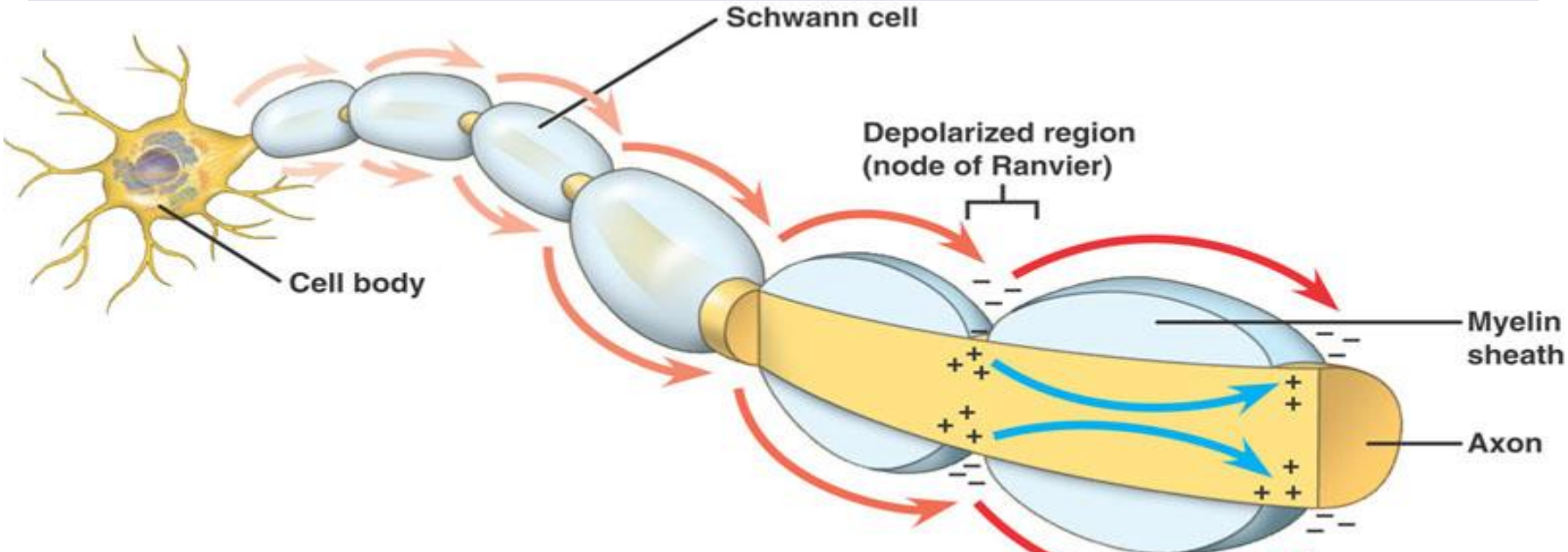
5 characteristics

- **Excitability (responsiveness)**
- **Conductivity**
- **Contractility**
- **Extensibility**
- **Elasticity**

- Excitability - ability to respond to tissue irritation change some of its properties. Indicator excitability - a threshold of irritation. This minimum force on the irritation that can trigger a visible response of a tissue.



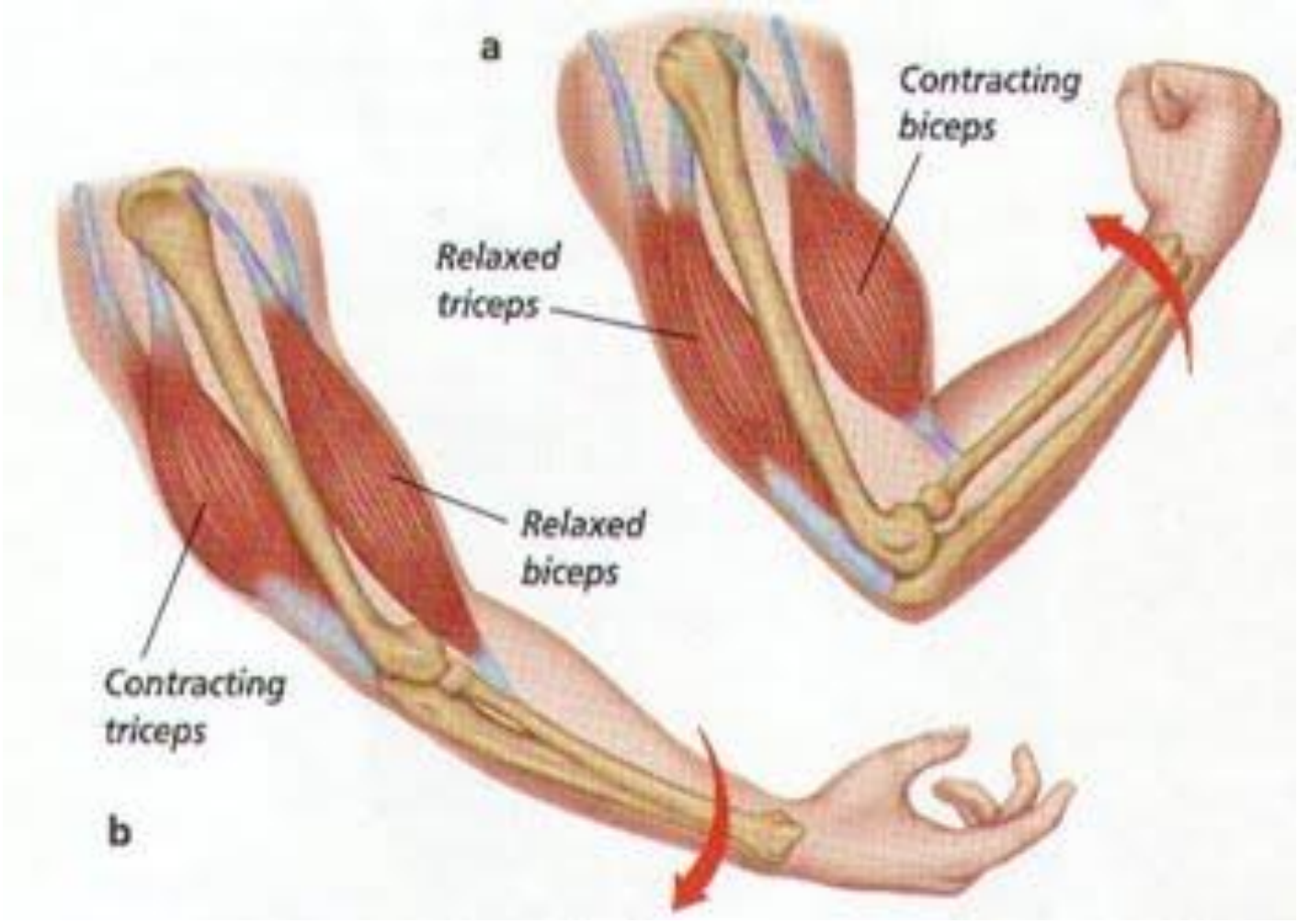
- Conductivity - the ability of the fabric to hold the excitement over its entire length. Conductivity display - the speed of the drive. Conductivity depends on the excitability of tissue: the higher excitability, the higher the conductivity.



- Refractory - the ability of the fabric to lose or reduce the excitability in the excitation process.
- In the course of the response of the tissue ceases to perceive the stimulus.
- Indicator refractory (refractory period) - the time during which the excitability of the tissue is reduced.

- Lability - the ability of the tissue to generate a certain number of excitation of waves per unit of time in strict accordance with the rhythm of the applied stimulus.
- Lability determined by the duration of the refractory period (the shorter the refractory period, the greater lability).

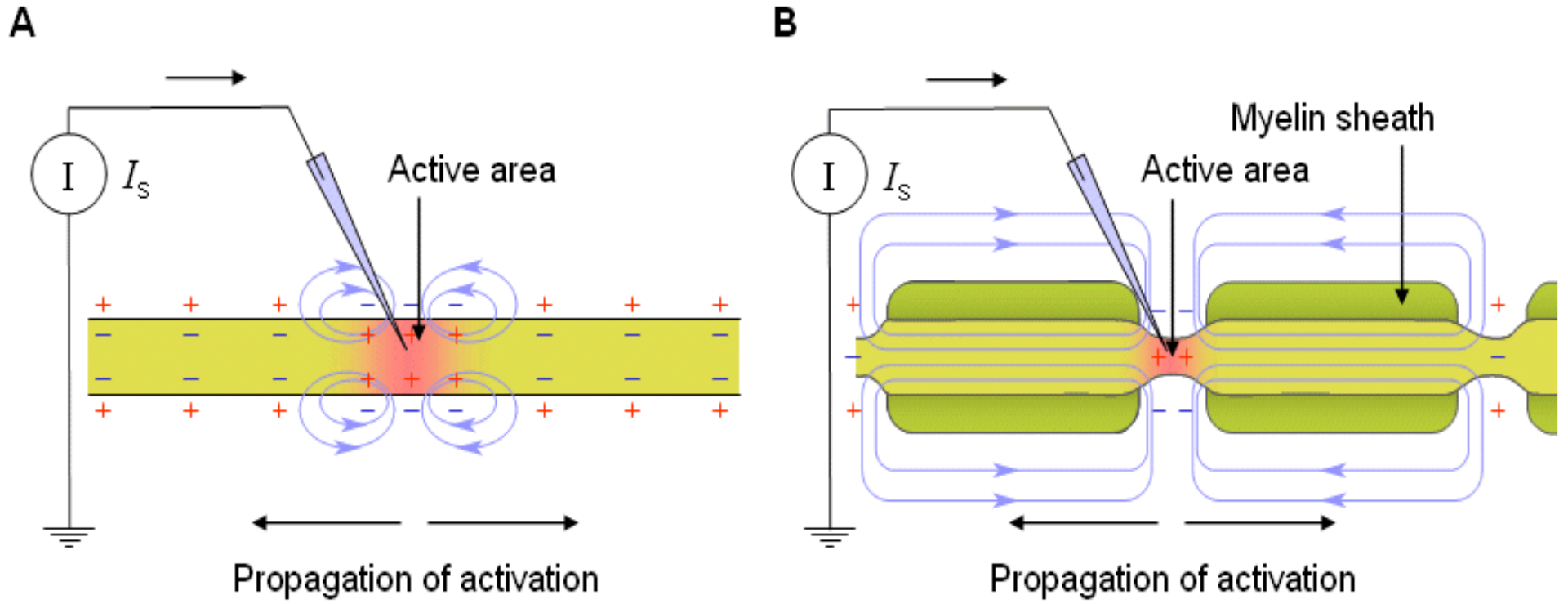
- Contractility - the ability of muscles to respond to the reduction in irritation.



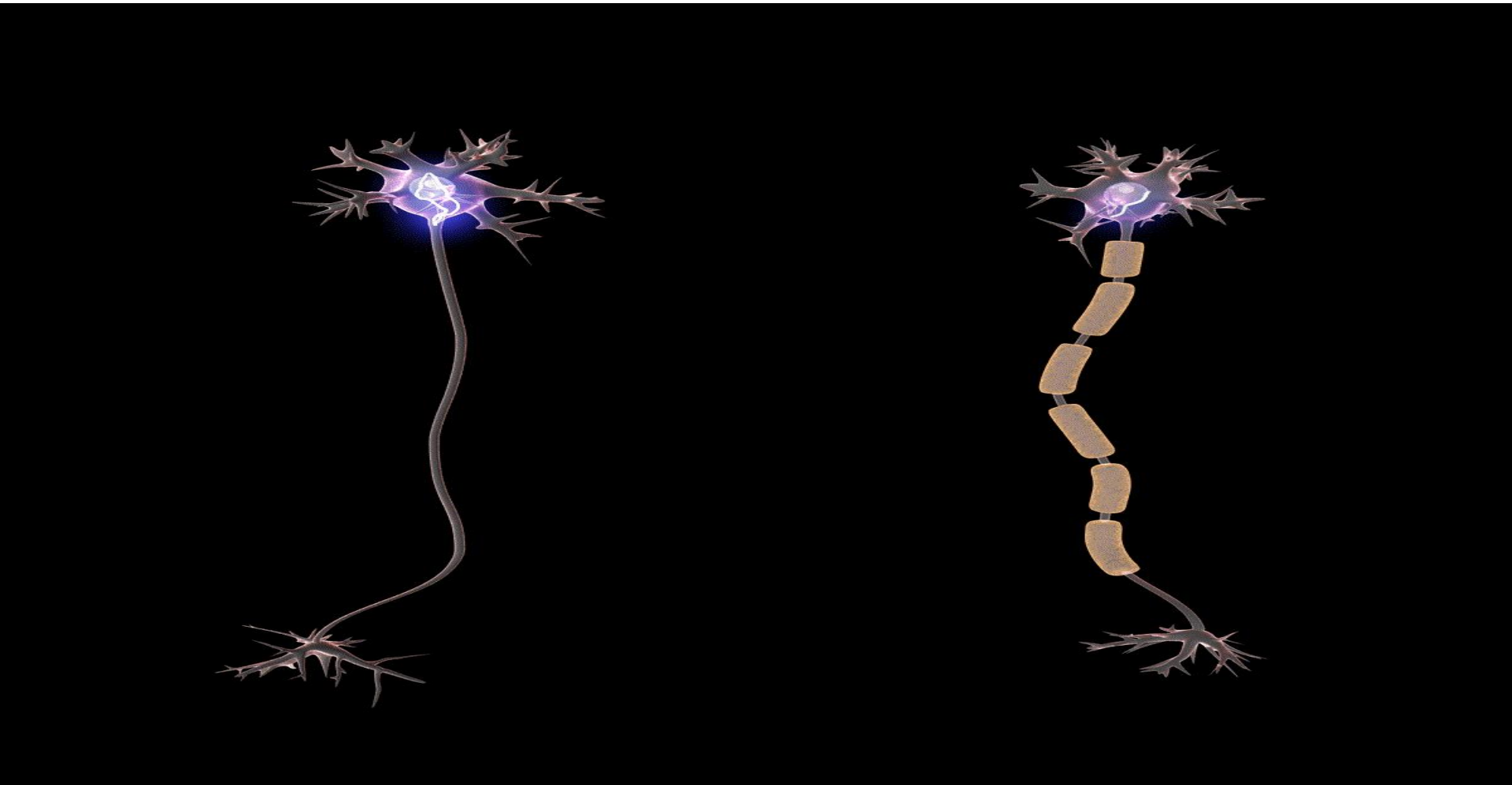
The mechanism of excitation along the nerve fiber.

- The main function of nerve fibers - transmission of nerve impulses.
- The speed of impulse conduction through the nerve fiber is high and depends on the presence of the myelin sheath and the fiber diameter.
- The larger the diameter, the higher the speed.

- Nerve fibers conduct excitation in both directions.
- Conducting impulses along nerve fibers isolated.
- Nerve fibers never tired.
- Excitation of the nerve fibers conducted without attenuation.



Nerve fibers are neuronal processes. There are 2 main types of fibers: myelinated and unmyelinated.



- Nerve fibers are divided into groups:

- A - nerve fibers with myelin sheath thickest. The highest rate of transmission of the nerve impulse.

- B - thinner myelin sheath, the speed of the drive below

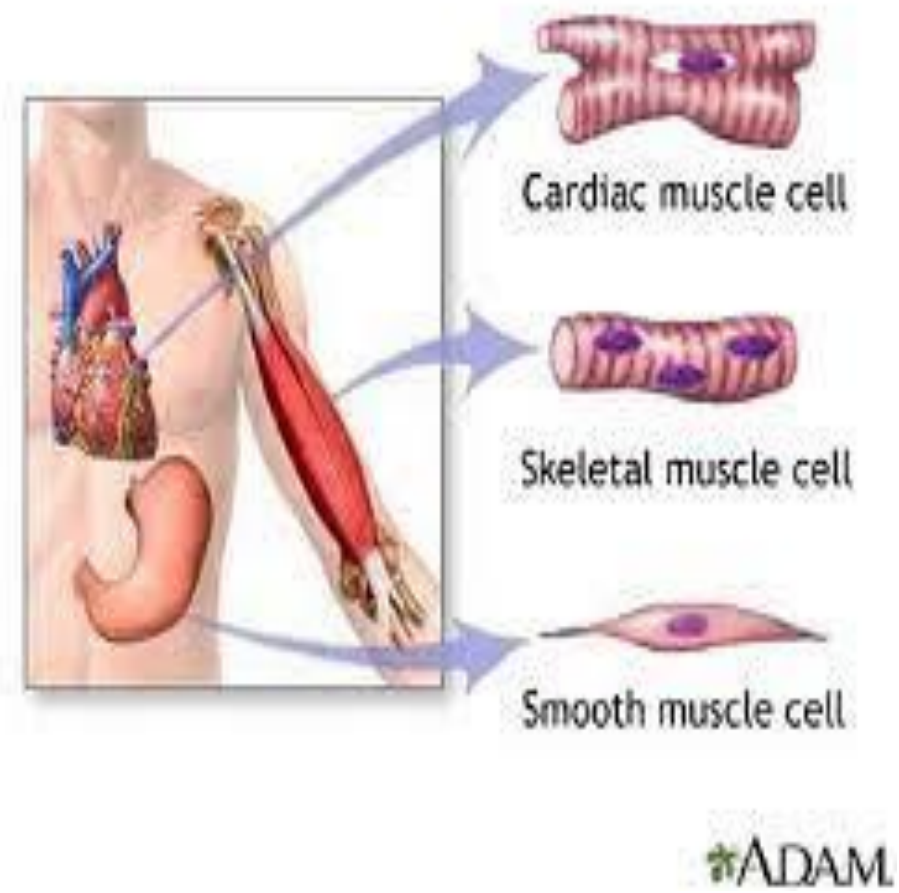
- C - unmyelinated fibers with a relatively low pulse rate.

In vertebrates and human three types of muscle

1) striated skeletal muscles,

2) striated muscle of the heart - the myocardium

3) smooth muscle forming the walls of the hollow internal organs and blood vessels.



The main functions of muscle tissue:

- motor - motion software
- static - providing fixation, including certain posture
- receptor - have receptors in muscles, allowing to perceive their own movement
- deposited - in the muscles are stocking water and some nutrients.

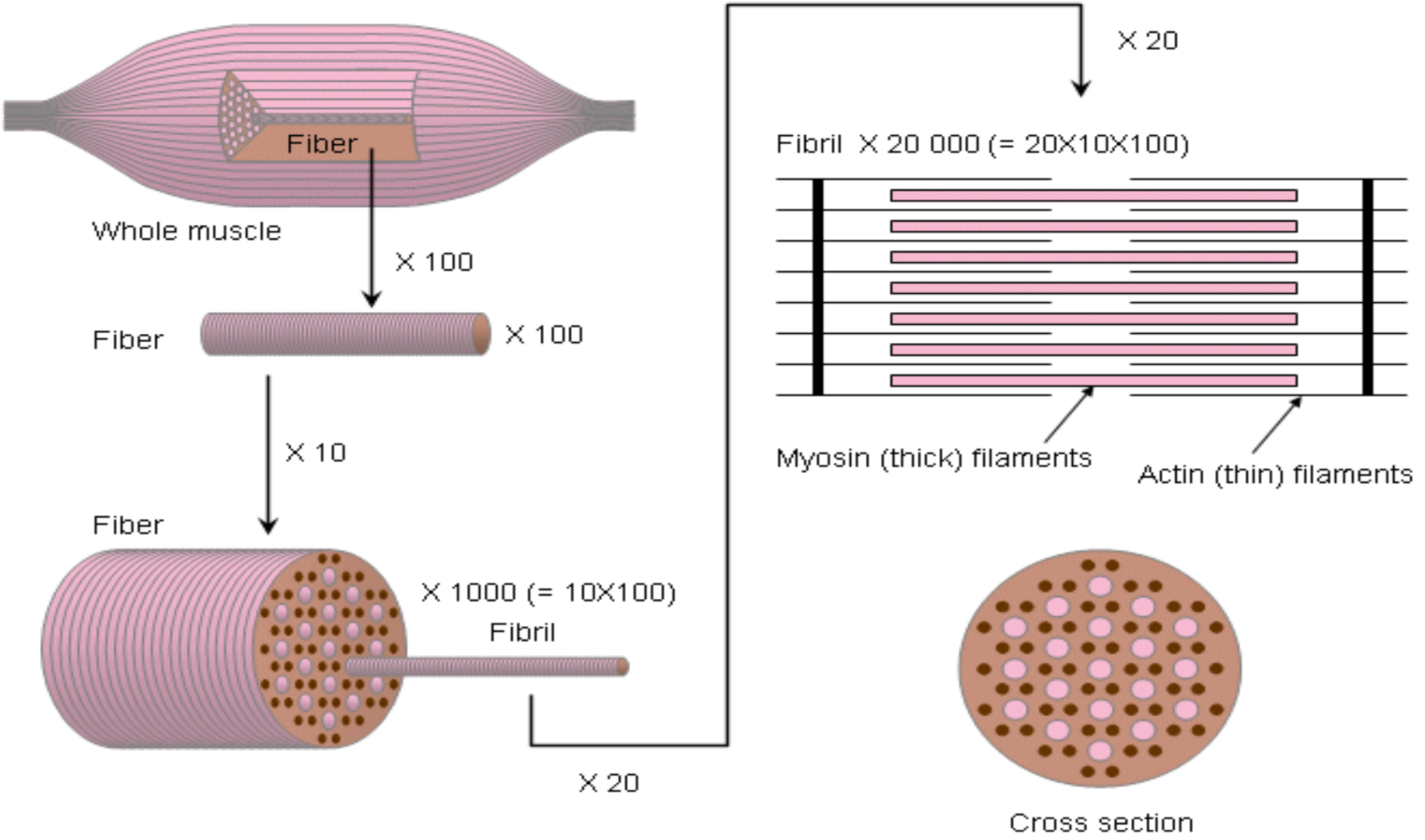
Characteristics of Muscle Tissue

- Contractility- the ability to shorten and thicken
- Excitability – ability of muscle tissue to receive and respond to stimuli
- Extensibility – ability of the muscle to stretch
- Elasticity – the ability of the muscle tissue to return to its original shape after contraction

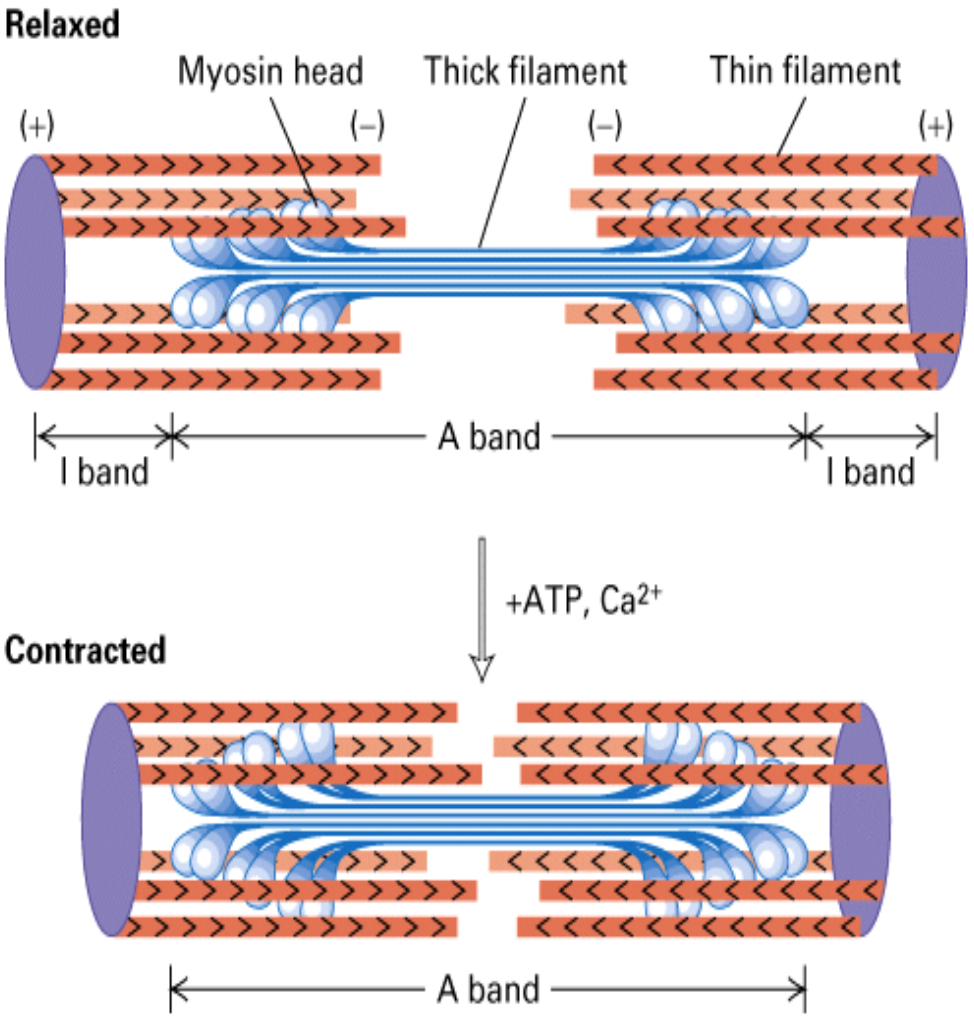
Mechanisms of muscle contraction and relaxation

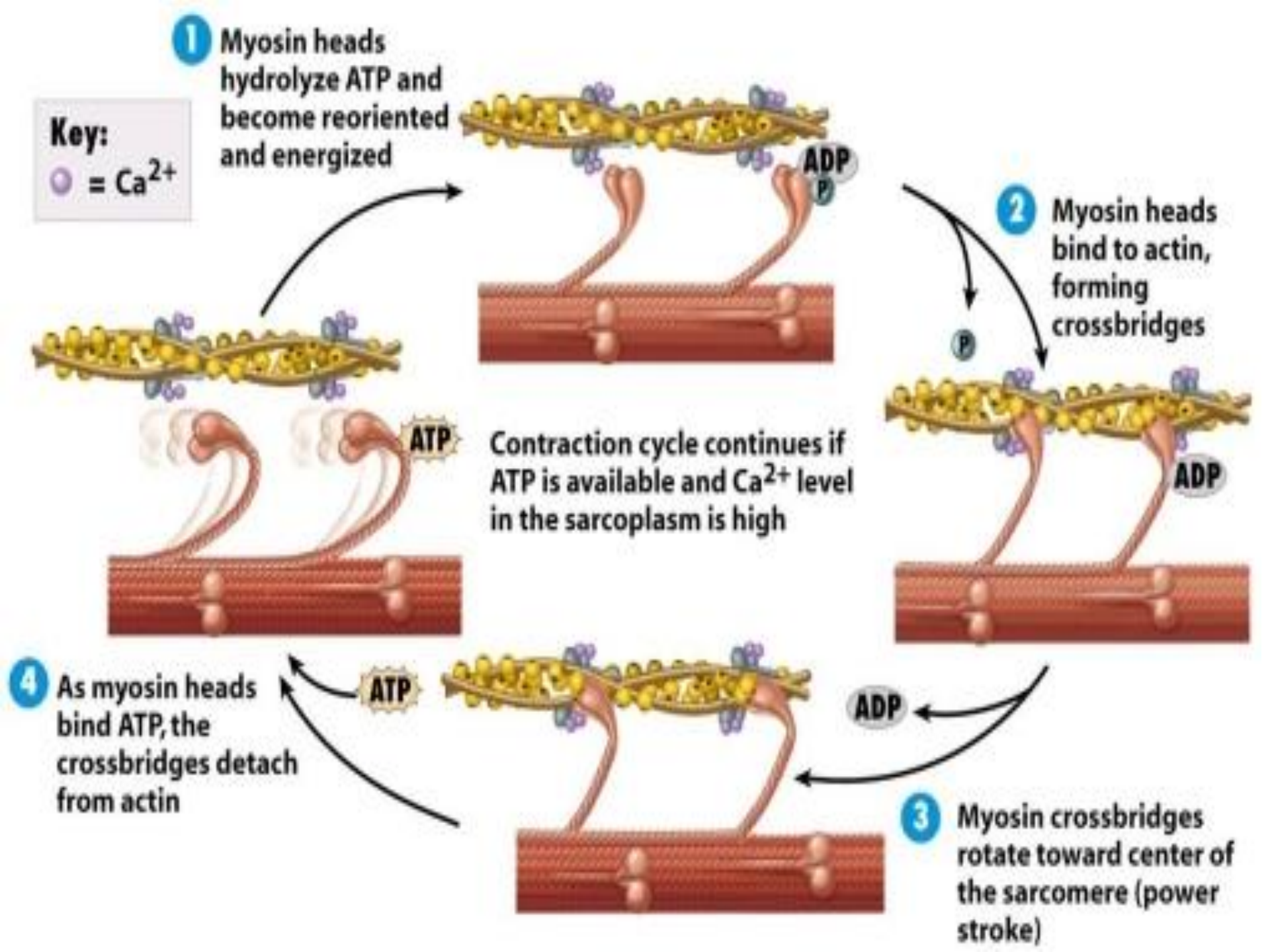
- Striated muscle consists of long fibers - myofibrils, which are located inside the filament of contractile proteins - actin and myosin.
- The filaments of myosin thick and does not move,
- thin actin filament capable to displacement.
- Actin filaments are coated with protein troponin, which prevents their interaction with myosin.
- The filaments of contractile proteins are surrounded by cytoplasm (sarcoplasm).

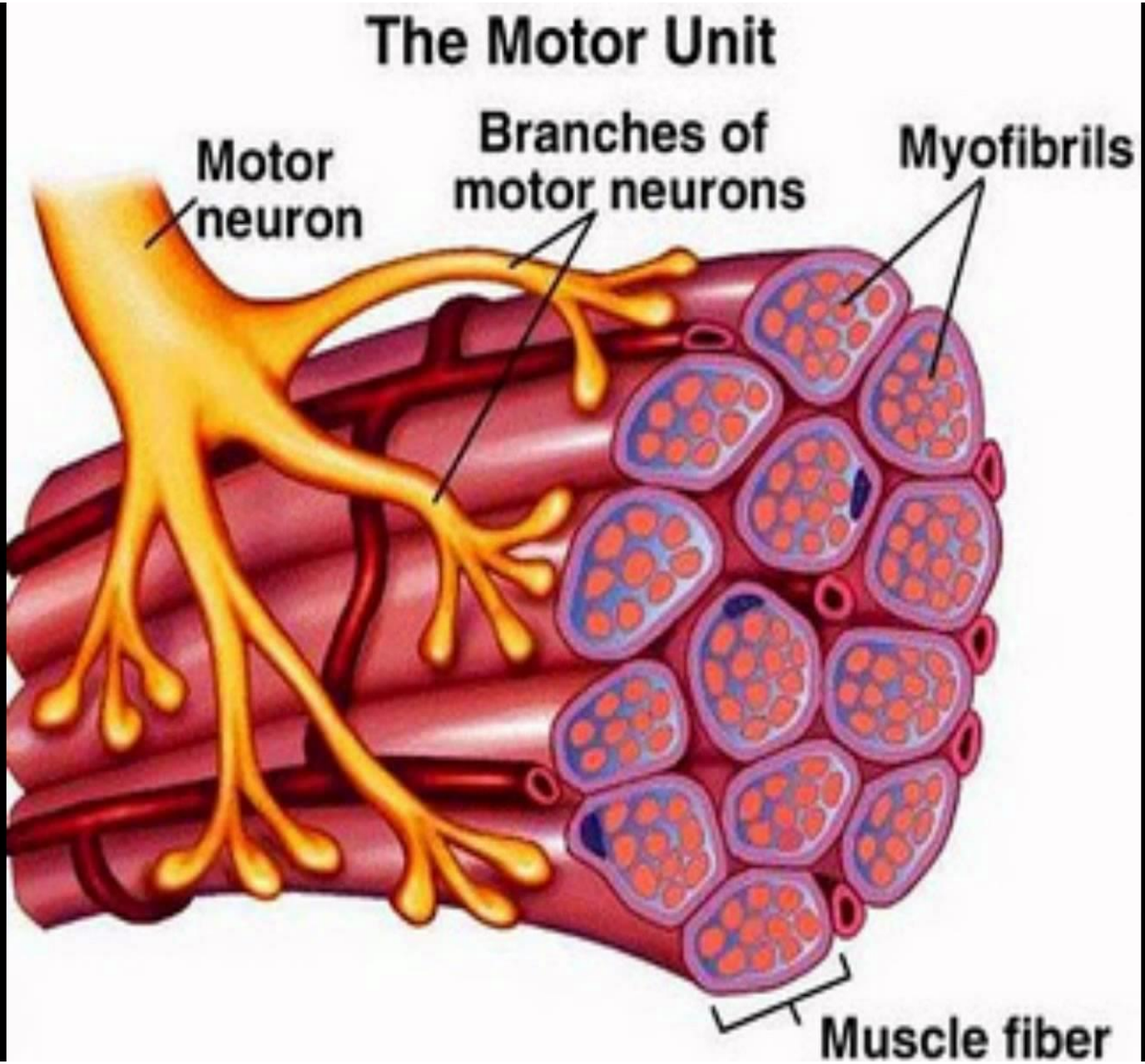
Anatomy of striated muscle



- To relax the muscles also need energy in the form of ATP molecules.
- As a result of this energy is the work of the calcium pump, which removes calcium ions from the sarcoplasmic.
- As a result of the released troponin molecule actin blocked, preventing its interaction with myosin.
- Threads again diverge, the muscle fiber relaxes.




1 Myosin heads hydrolyze ATP and become reoriented and energized
Key:
= Ca^{2+}
ADP
P
2 Myosin heads bind to actin, forming crossbridges
P
ADP
ATP
Contraction cycle continues if ATP is available and Ca^{2+} level in the sarcoplasm is high
4 As myosin heads bind ATP, the crossbridges detach from actin
ATP
ADP
3 Myosin crossbridges rotate toward center of the sarcomere (power stroke)


The Motor Unit
Motor neuron
Branches of motor neurons
Myofibrils
Muscle fiber

- In isotonic contraction of the muscle fiber length changes without changing the tone. This reduction occurs when the load does not move a muscle.

- In isometric contraction stress increases muscle fiber without changing its length. This contraction of the muscle may be obtained to raise unbearable burden when trying to.

- The whole body muscle contractions are always mixed
- There is a change, and the length and muscle tension.

- With the reduction of muscle ATP chemical energy is converted into heat and mechanical energy.
- When muscle contraction generates heat.
- There are two phases of heat - the start (during contraction), and delayed.
- The initial phase is dependent on the chemical processes that convert muscle from rest to an active state.
- The second phase is associated with the processes that provide re-synthesis of ATP

Hill's equations for muscle contraction

- This is a popular state equation applicable to skeletal muscle that has been stimulated to show ***Tetanic contraction***. It relates tension to velocity with regard to the internal thermodynamics.
- The equation is

$$(\vartheta + b)(F + a) = b(F_0 + a)$$

where

- **F** is the tension (or load) in the muscle
- $\boldsymbol{v}$ is the velocity of contraction
- F**0** is the maximum isometric tension (or load) generated in the muscle
- **a** – coefficient of shortening heat
- $\boldsymbol{v}0$ is the maximum velocity, when F=0

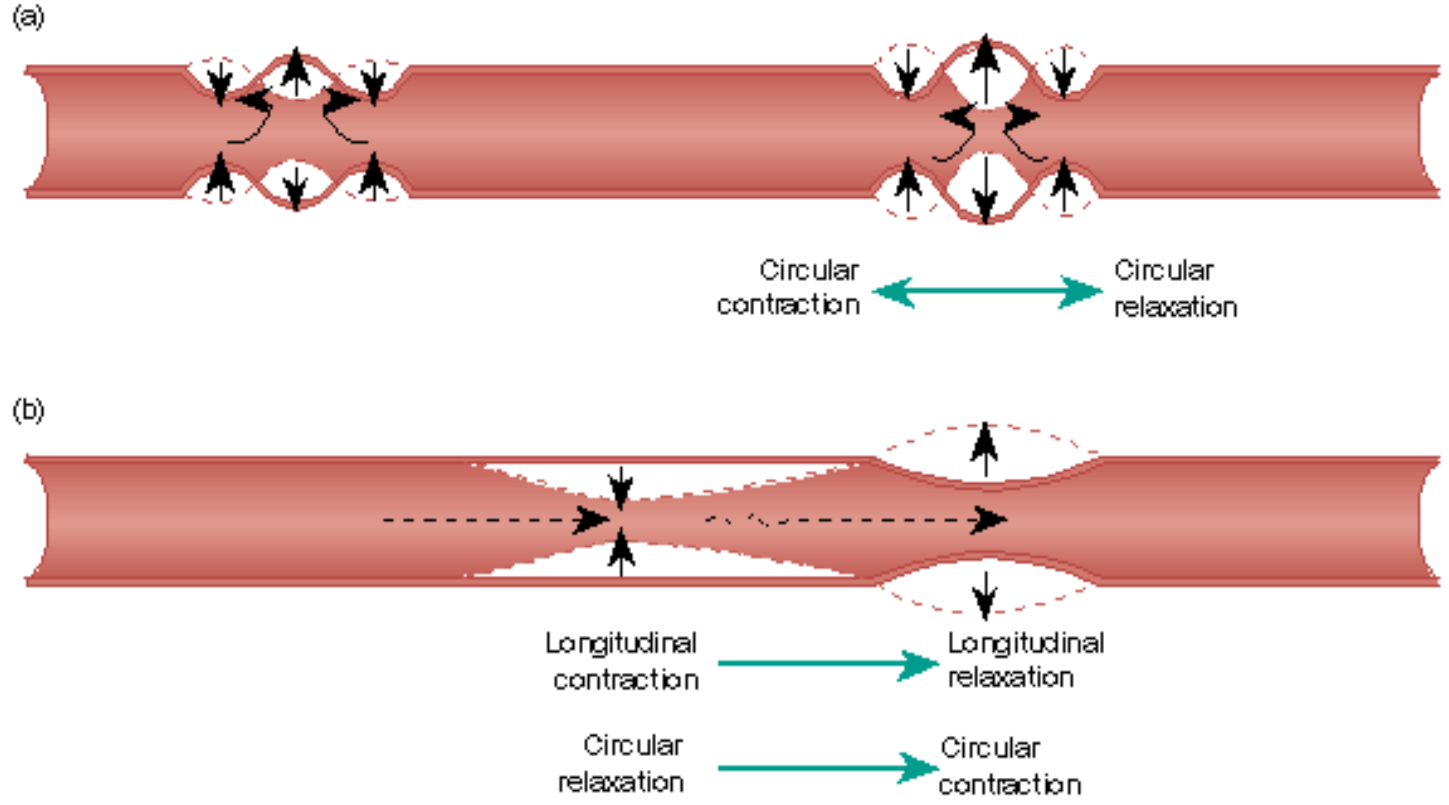
$$b = a \cdot \frac{\vartheta_0}{F_0}$$

Smooth muscle.

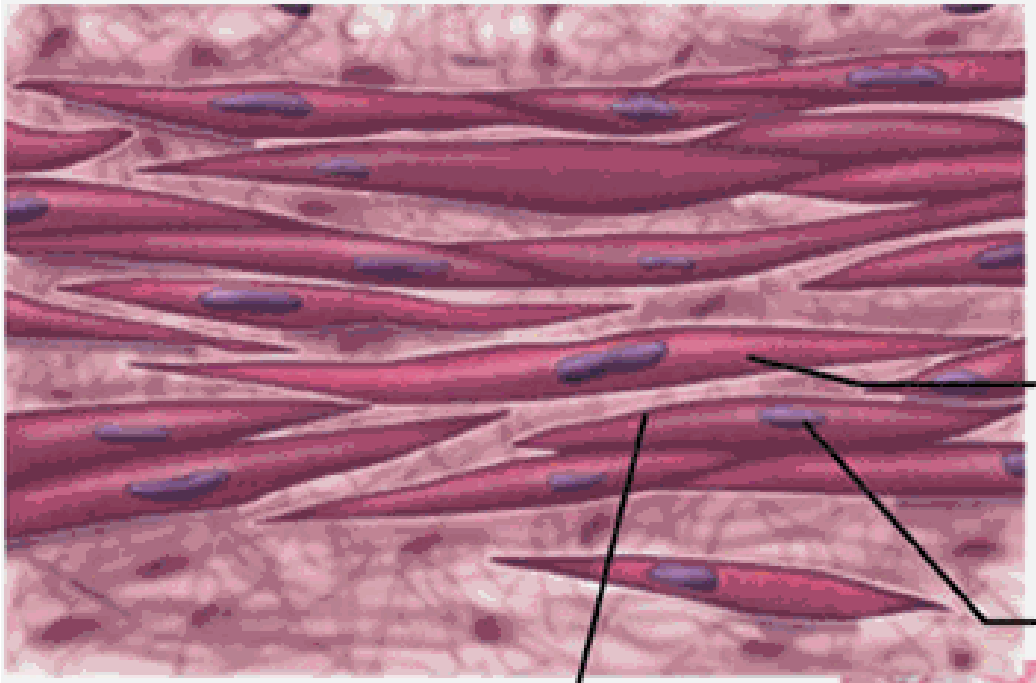
- Smooth muscles form a wall (muscle layer) of the internal organs and blood vessels.
- Smooth muscles are less excitable than striated.
- Excitation with low speed spread thereon - 2-15 cm / s.
- Unlike nerve fibers and fibers of striated muscle, smooth muscle excitation may be transferred from one fiber to another

- A feature of smooth muscle is their ability to carry out a relatively slow movement and long-term tonic contractions.

- Slowly, with a rhythmic character, reduction of gastric smooth muscle, intestine, ureter and other organs provide moving the contents of these bodies.

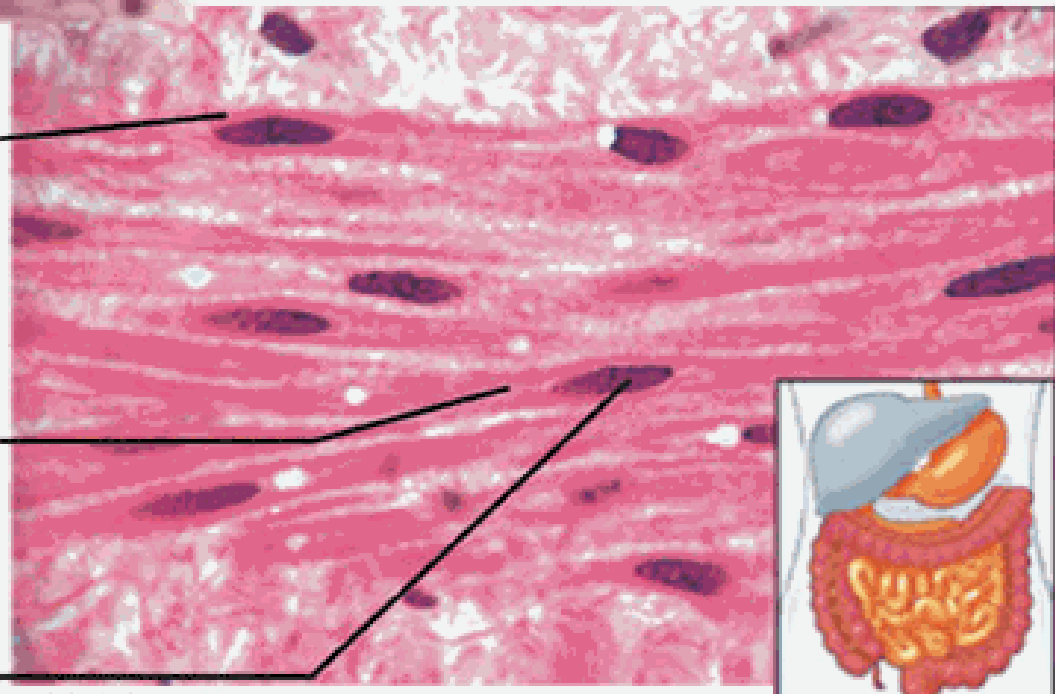


Smooth Muscle Tissue



Cytoplasm

Nucleus



Cell membrane

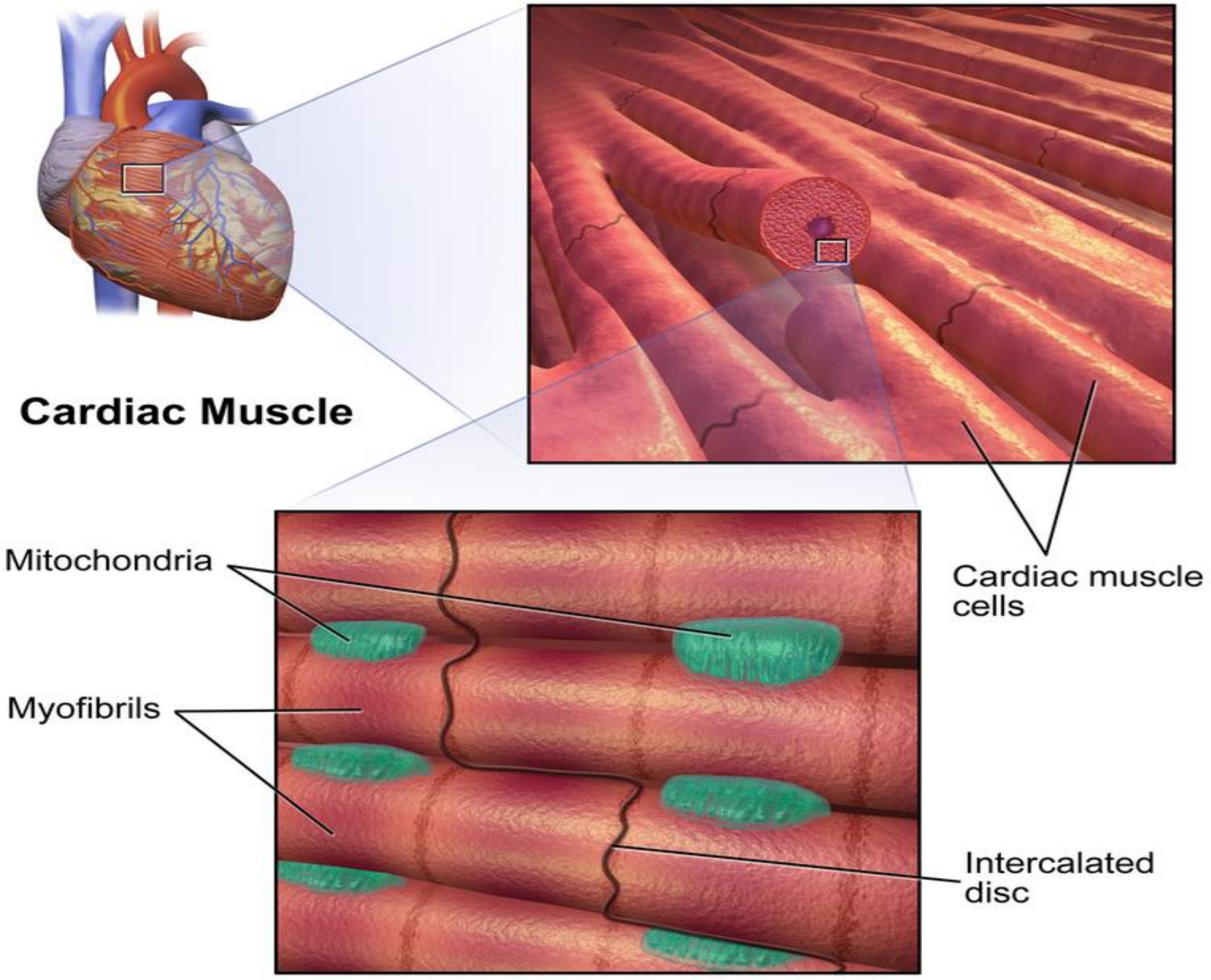
Cytoplasm

Nucleus

- A characteristic feature of smooth muscle is their ability to automatic operation, which has a myogenic origin and occurs in muscle cells, which perform the function of the pacemaker.
- Automatism of smooth muscle fibers of the stomach, intestines, uterus, ureter shown their ability to contract rhythmically, in the absence of external stimuli, without the influence of nerve impulses.

Action potential of cardiomyocytes

- **Cardiomyocytes -** heart muscle cells.
- The **cardiac action potential** is a short-lasting event in which *the membrane potential* (the difference of potential between the interior and the exterior) *of a cardiac cell* rises and falls following a consistent trajectory, similar to the action potential in other types of cells.


Cardiac Muscle
Mitochondria
Myofibrils
Cardiac muscle cells
Intercalated disc

- Two main forces drive ions across cell membranes:
  - ***Chemical potential:*** an ion will move down its *concentration gradient.*
  - ***Electrical potential:*** an ion will move away from ions/molecules of like charge.
- The **transmembrane potential (TMP)** is the electrical potential difference (voltage) between the inside and the outside of a cell. When there is a *net* movement of +ve ions *into* a cell, the TMP becomes more +ve, and when there is a *net* movement of +ve ions *out*of a cell, TMP becomes more –ve.
- Ion channels help maintain ionic concentration gradients and charge differentials between the inside and outside of the cardiomyocytes.

Intra- and extracellular ion concentrations (mmol/L)

Element	Ion	Extracellular	Intracellular	Ratio
Sodium	Na^+	135 - 145	10	14:1
Potassium	K^+	3.5 - 5.0	155	1:30
Chloride	Cl^-	95 - 110	10 - 20	4:1
Calcium	Ca^{2+}	2	10^{-4}	2×10^4:1

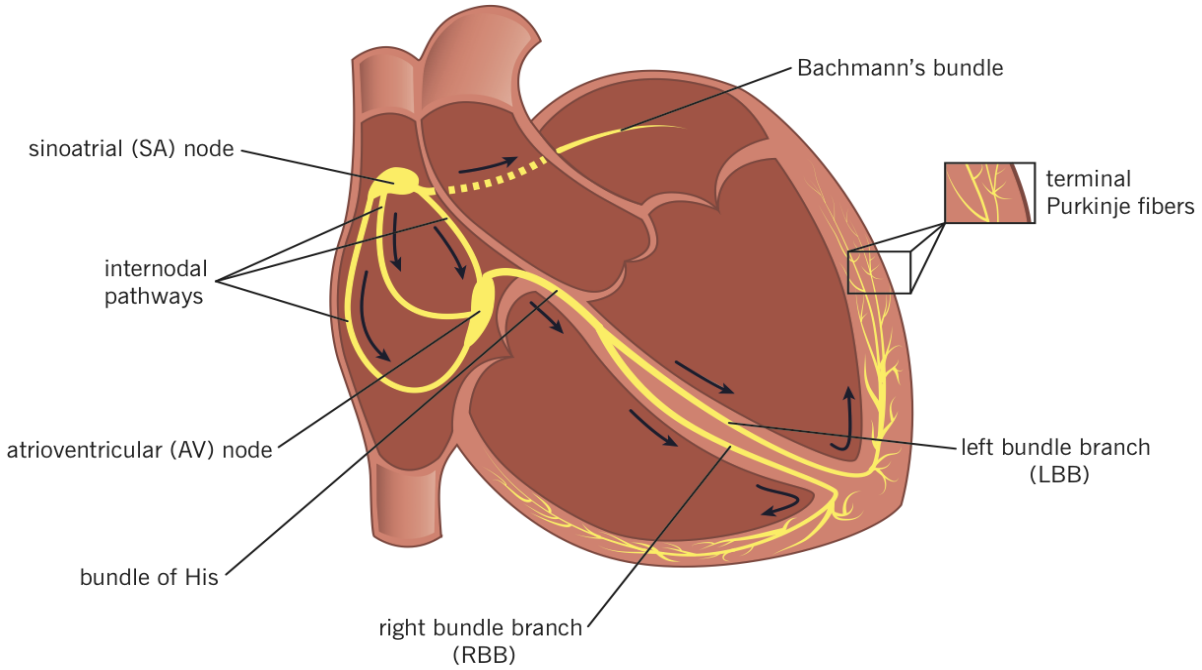
Properties of cardiac ion channels

- **Selectivity***:* they are only permeable to a single type of ion based on their physical configuration.

- **Voltage-sensitive gating**: a specific TMP range is required for a particular channel to be in open configuration; at all TMPs outside this range, the channel will be closed and impermeable to ions. Therefore, specific channels open and close as the TMP changes during cell depolarization and repolarization, allowing the passage of different ions at different times.

- **Time-dependence**: *some* ion channels (importantly, fast Na^+ channels) are configured to close a fraction of a second after opening; they cannot be opened again until the TMP is back to resting levels, thereby preventing further excessive influx.

- **Action potential**: electrical stimulation created by a sequence of ion fluxes through specialized channels in the membrane (*sarcolemma*) of cardiomyocytes that leads to cardiac contraction.

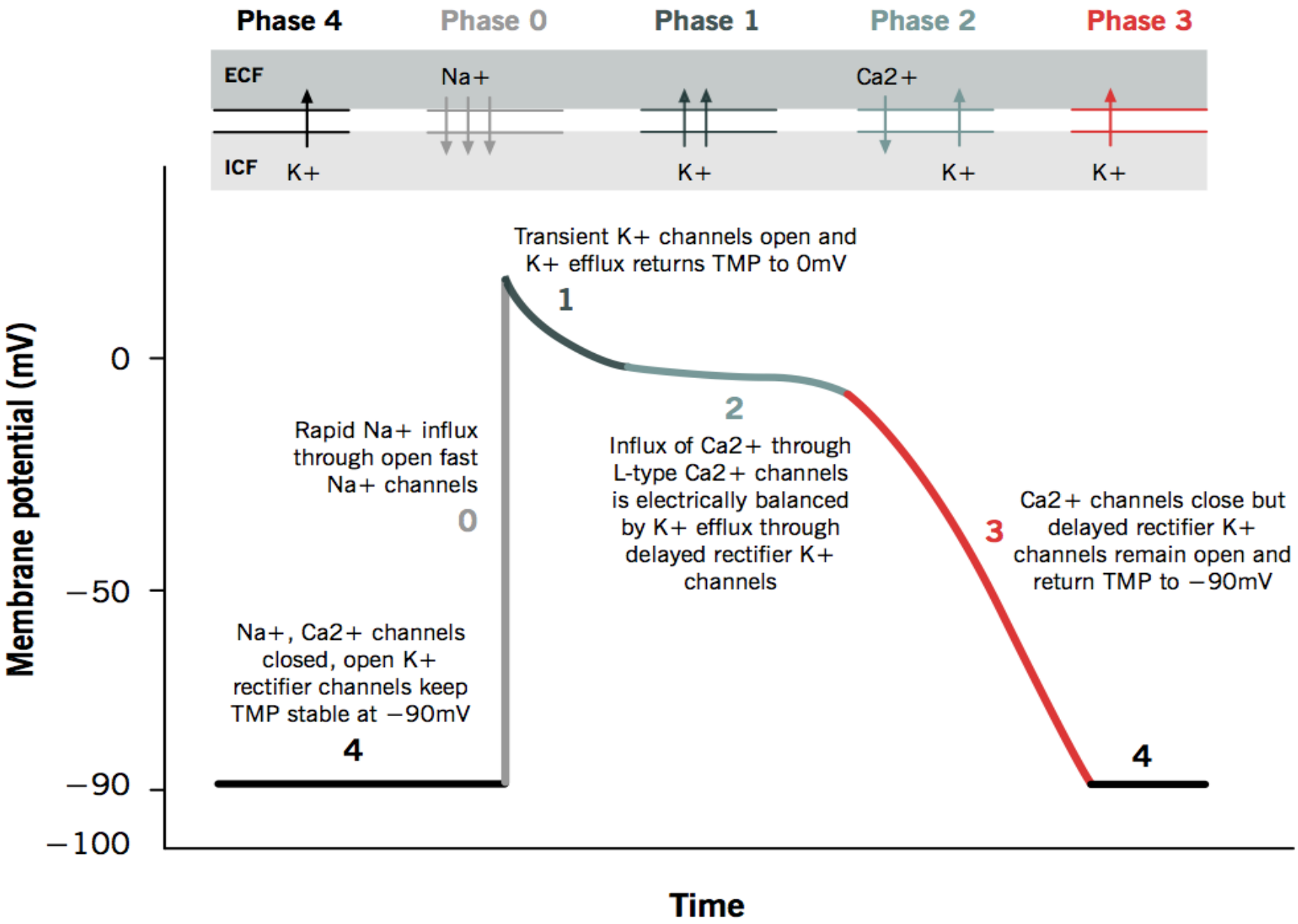


The action potential in typical cardiomyocytes is composed of 5 phases (0-4), beginning and ending with phase 4.

- Phase 4: The resting phase
- Phase 0: Depolarization
- Phase 1: Early repolarization
- Phase 2: The plateau phase
- Phase 3: Repolarization

Action potential of cardiac muscles

Grigoriy Ikonnikov and Eric Wong



- **Phase 4: The resting phase**
- The resting potential in a cardiomyocyte is −90 mV due to a constant outward leak of K^+ through *inward rectifier channels.*
- Na^+ and Ca^{2+} channels are closed at resting TMP.

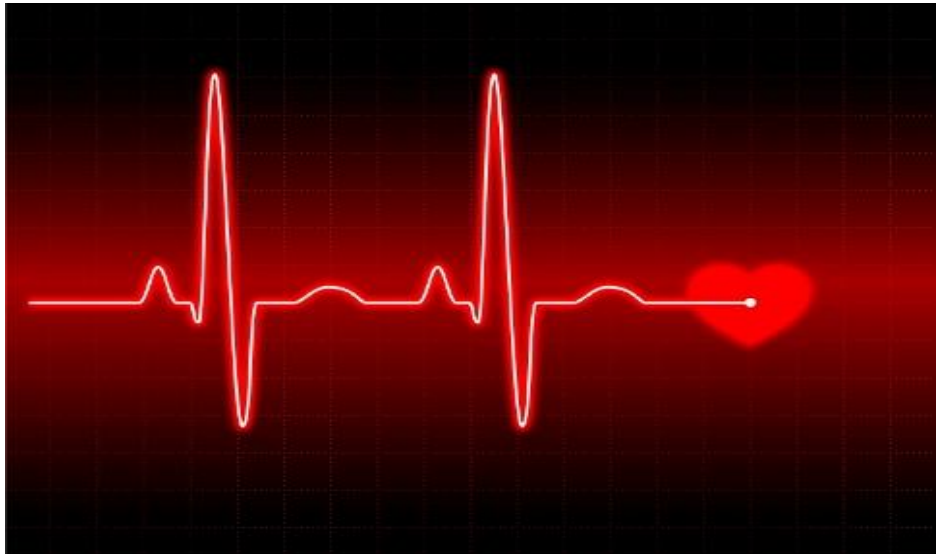
- **Phase 0: Depolarization**
- An action potential triggered in a neighbouring cardiomyocyte or pacemaker cell causes the TMP to rise above −90 mV.
- Fast Na^+ channels start to open one by one and Na^+ leaks into the cell, further raising the TMP.
- TMP approaches −70mV, the **threshold potential** in cardiomyocytes, i.e. the point at which enough fast Na^+ channels have opened to generate a self-sustaining inward Na^+ current.
- The large Na^+ current rapidly depolarizes the TMP to 0 mV and slightly *above* 0 mV for a transient period of time called the **overshoot**; fast Na^+ channels close (recall that fast Na^+ channels are *time-dependent*).
- L-type ("long-opening") Ca^{2+} channels open when the TMP is *greater than* −40 mV and cause a small but steady influx of Ca^{2+} down its concentration gradient.

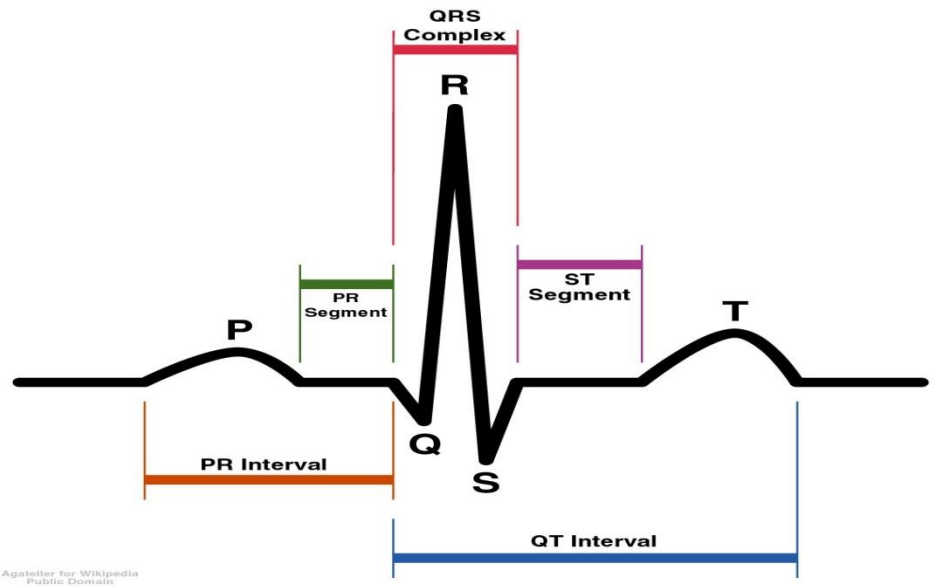
- **Phase 1: Early repolarization**
- TMP is now slightly positive.
- Some K^+ channels open briefly and an outward flow of K^+ returns the TMP to approximately 0 mV.
- **Phase 2: The plateau phase**
- L-type Ca^{2+} channels are still open and there is a small, constant inward current of Ca^{2+}. This becomes significant in the *excitation-contraction coupling* process described below.
- K^+ leaks out down its concentration gradient through *delayed rectifier* K^+ channels.
- These two countercurrents are electrically balanced, and the TMP is maintained at a *plateau* just below 0 mV throughout phase 2.

- **Phase 3: Repolarization**
- Ca^{2+} channels are gradually inactivated.
- Persistent outflow of K^+, now exceeding Ca^{2+} inflow, brings TMP back towards resting potential of −90 mV to prepare the cell for a new cycle of depolarization.
- Normal transmembrane ionic concentration gradients are restored by returning Na^+ and Ca^{2+} ions to the extracellular environment, and K^+ ions to the cell interior. The pumps involved include the sarcolemmal *Na^+-Ca^{2+} exchanger*, *Ca^{2+}-ATPase* and *Na^+-K^+-ATPase*.

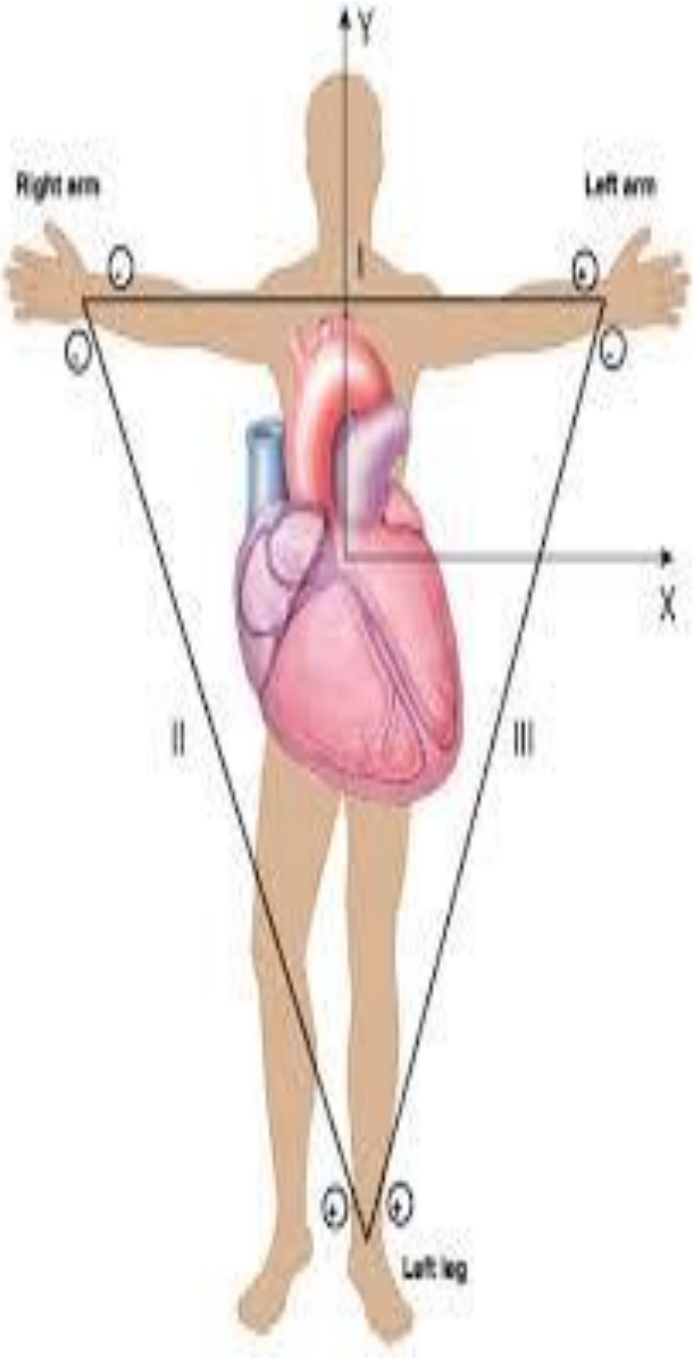
Electrocardiography

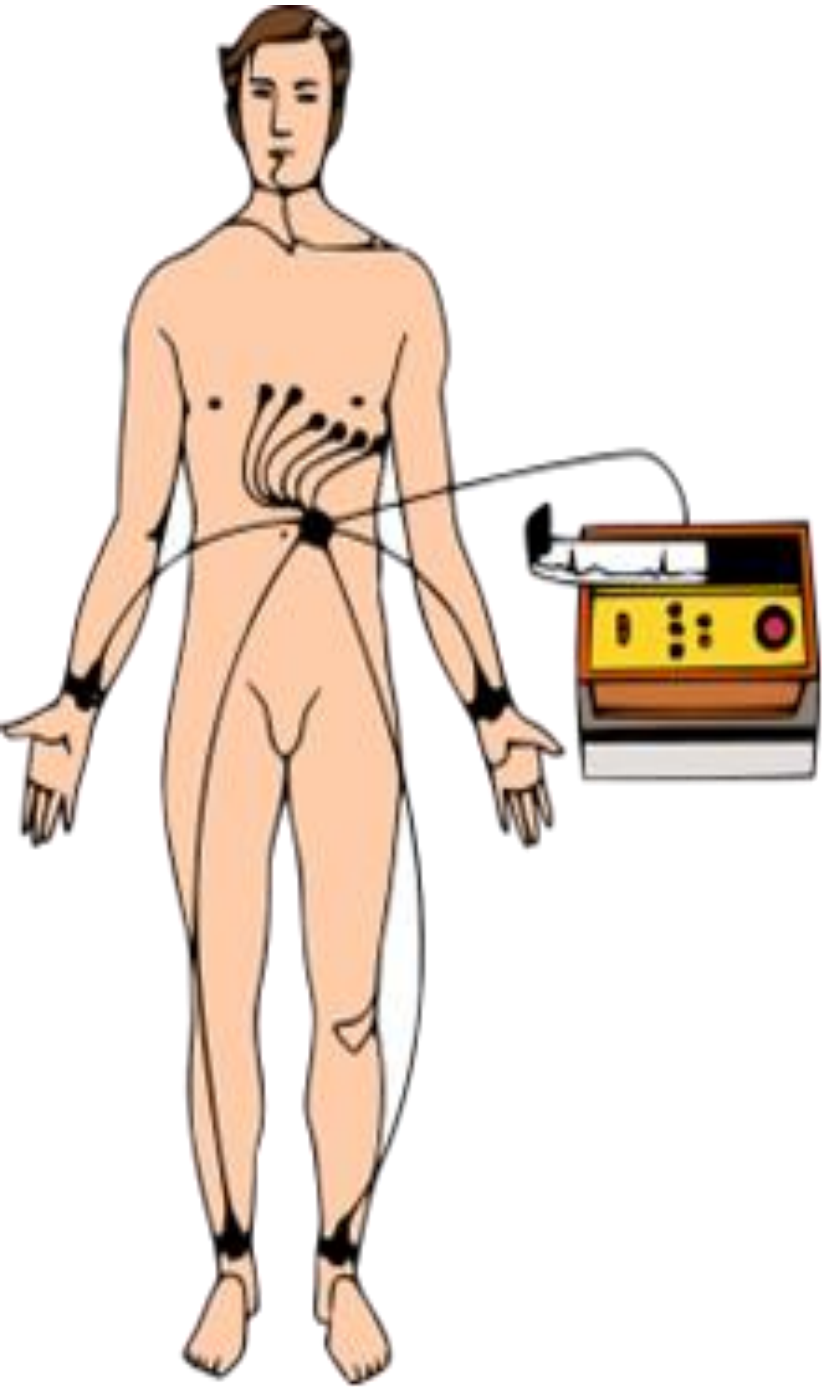
- **Electrocardiography** (**ECG** or **EKG***) is the process of recording the electrical activity of the heart over a period of time using electrodes placed on a patient's body. These electrodes detect the tiny electrical changes on the skin that arise from the heart muscle depolarizing during each heartbeat.





Einthoven theory - theory of the formation of the electrocardiogram, according to which the heart is regarded as infinitely small dipole, located in the center of the triangle Einthoven and continuously changing the magnitude and direction of the vector of the electromotive force; the projection of each of the parties to determine the shape of a triangle in three standard electrocardiogram leads.



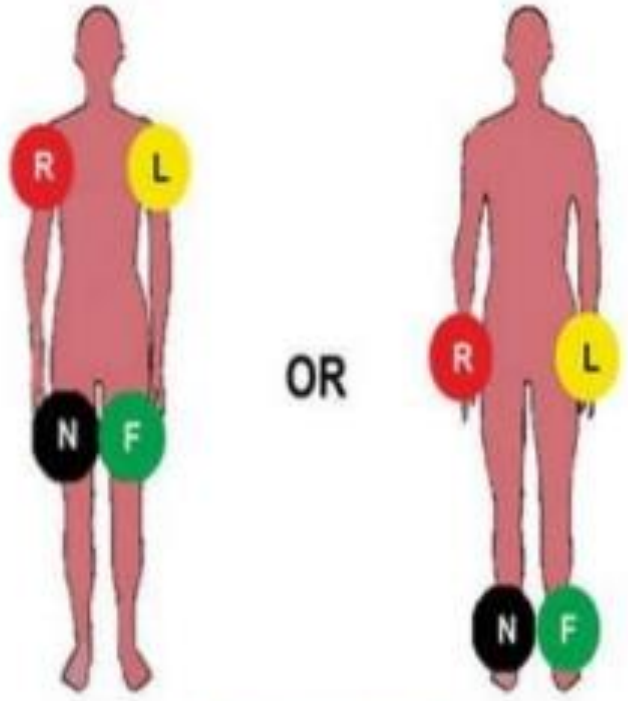


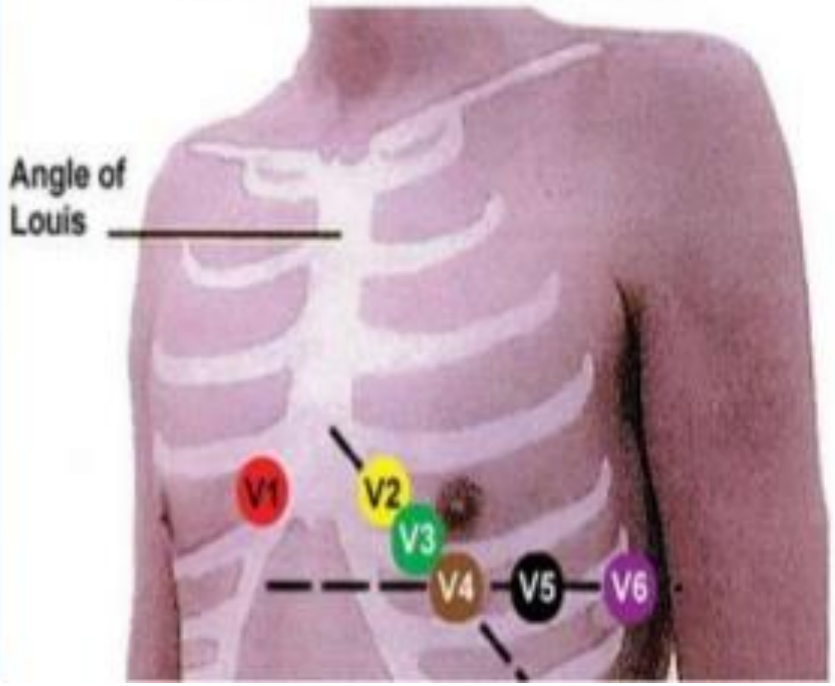
- the word *lead* may refer to the tracing of the voltage difference between two of the electrodes and is what is actually produced by the ECG recorder.
- Each will have a specific name. For example **"lead I"** is the voltage **between** the **right arm electrode and the left arm electrode**, where as **"Lead II"** is the voltage between the **right arm and the feet**.

- **Typically connections of electrodes to the patient: by the traffic light color in a clockwise direction**

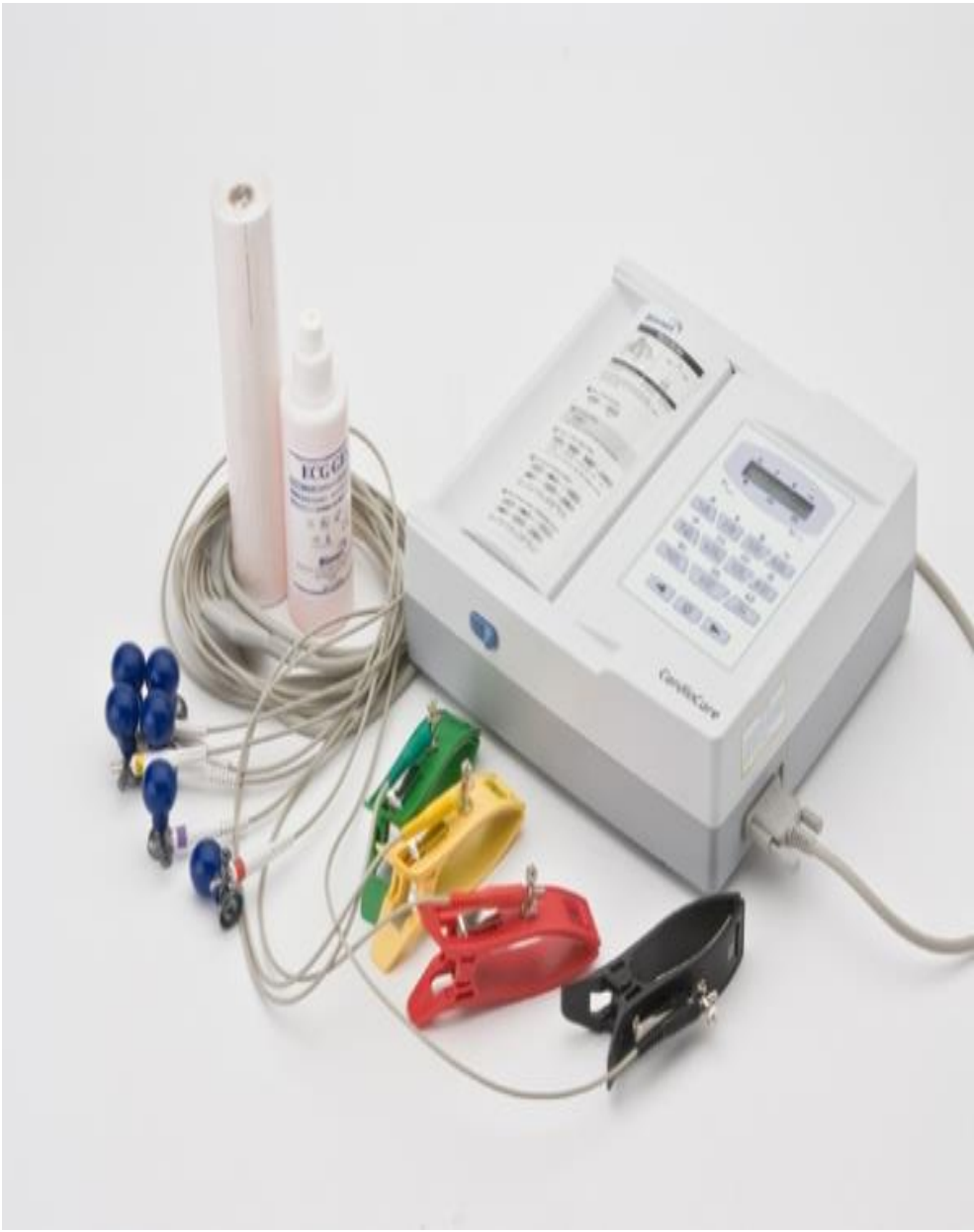
Limb Lead Placement

- Connect the lead wires to the electrodes. The tip of each lead wire is lettered and color-coded for easy identification.
- The red or RA lead wire goes to the right arm
- The yellow or LA lead wire goes to left arm
- The black or N/ RL lead wire goes to right leg
- The green or LL lead wire goes to left leg



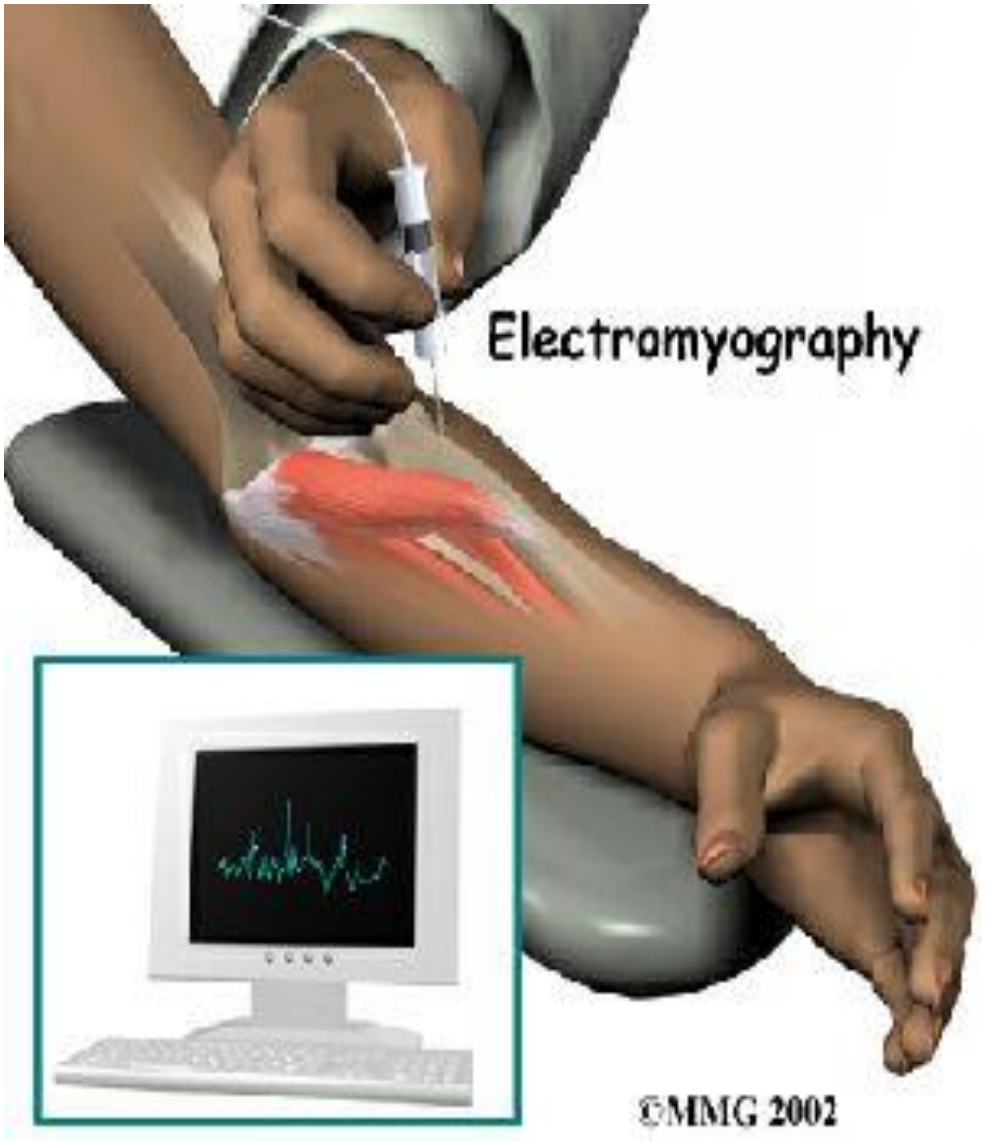


Electrocardiograph (ECG) - a device to record changes of the electric field potential difference (biopotential) of the heart.

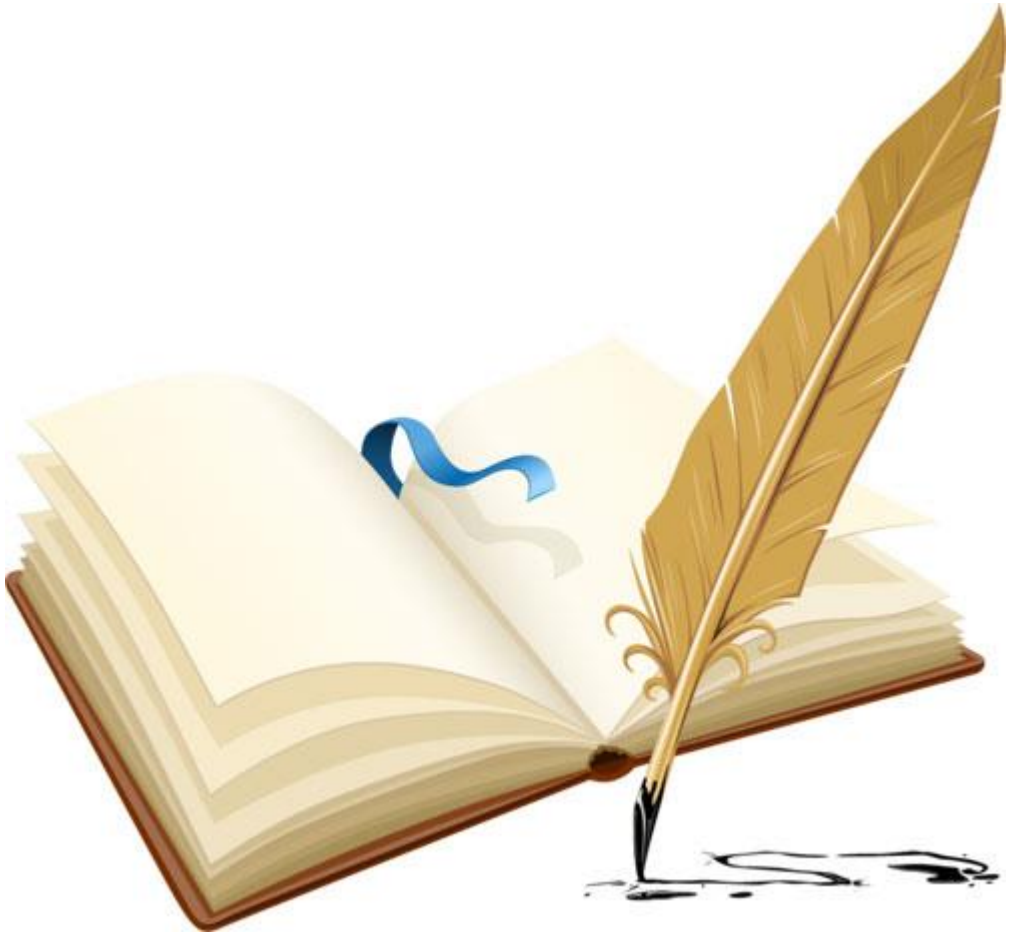


Electromyography

- Electromyography - (myo - muscle and ... graph - writing), method of research of bioelectric potentials that arise in the skeletal muscles of humans and animals in the excitation of the muscle fibers; Checking the electrical activity of muscles.



Thank you for the attention !!!!!!



Physical basics of electrocardiography. Registration of ECG and principles of analysis.

Electrocardiography

- **Electrocardiography** (**ECG** or **EKG**) is the process of recording the electrical activity of the heart over a period of time using electrodes placed on a patient's body.
- These electrodes detect the tiny electrical changes on the skin that arise from the heart muscle depolarizing during each heartbeat.

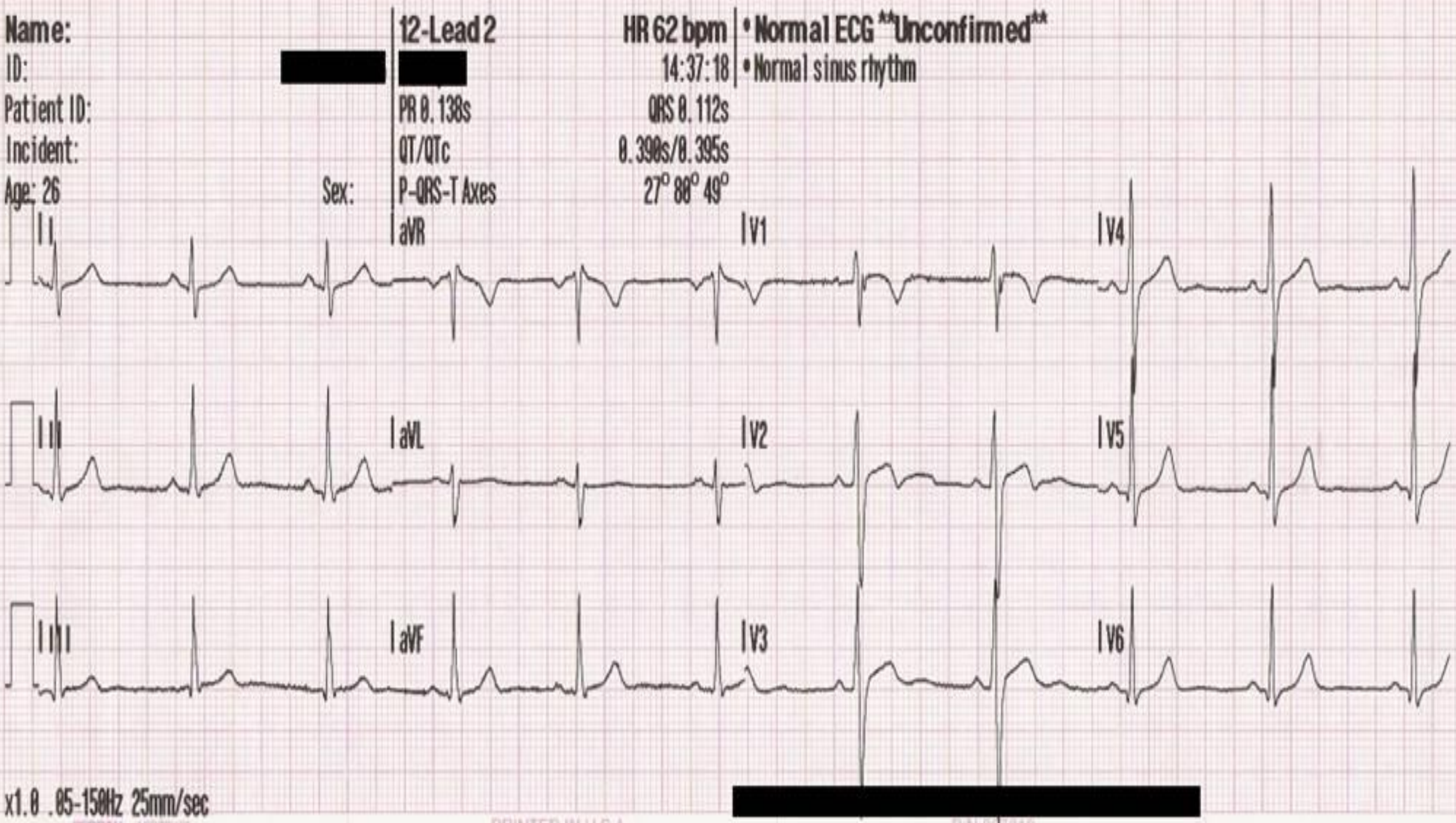
What is an Electrocardiogram?

- An electrocardiogram, also called an EKG or ECG, is a simple, painless test that records the heart's electrical activity. To understand this test, it helps to understand how the heart works.
- With each heartbeat, an electrical signal spreads from the top of the heart to the bottom. As it travels, the signal causes the heart to contract and pump blood. The process repeats with each new heartbeat.
- The heart's electrical signals set the rhythm of the heartbeat.

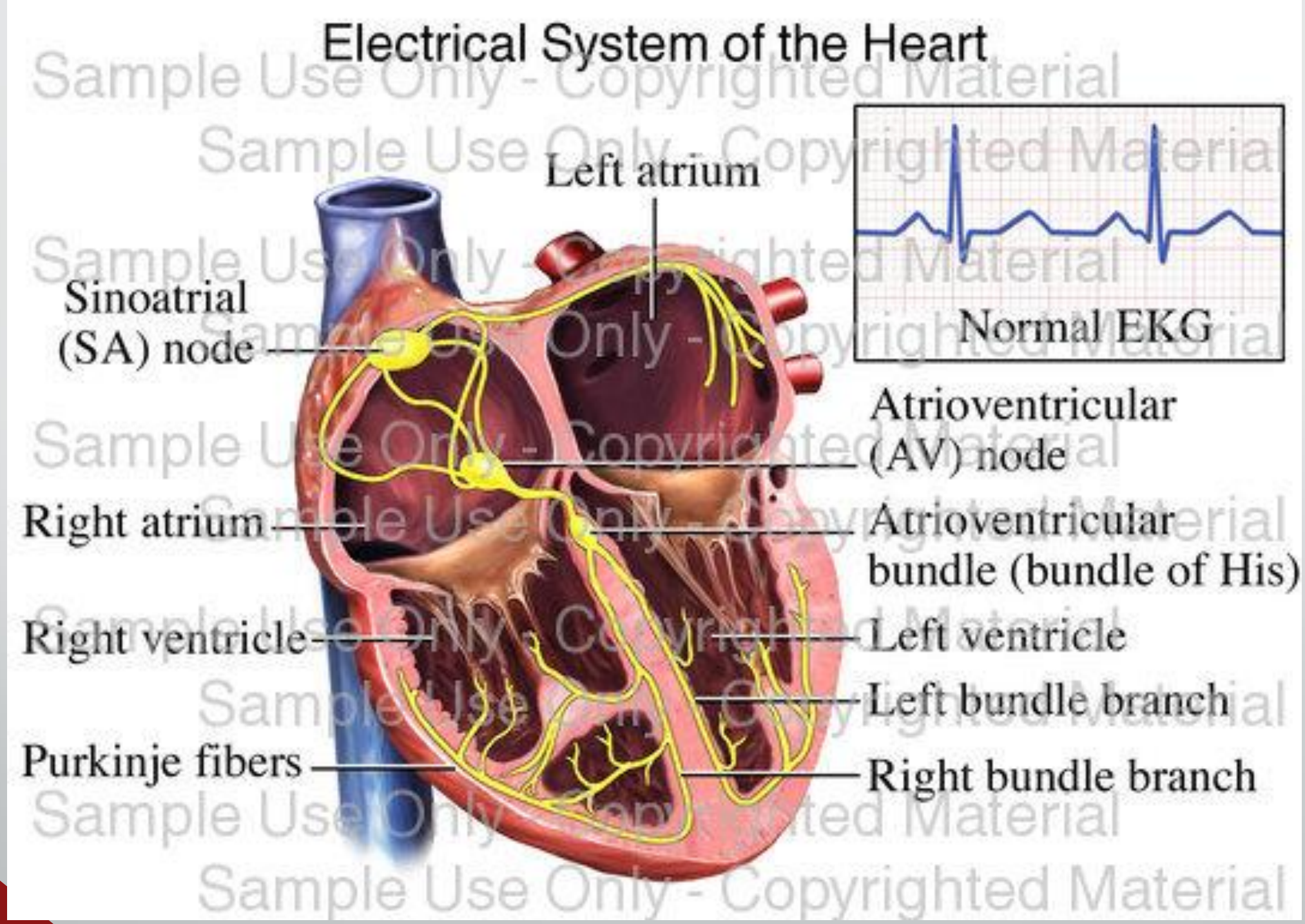
.

An EKG shows:

- How fast your heart is beating
- Whether the rhythm of your heartbeat is steady or irregular
- The strength and timing of electrical signals as they pass through each part of your heart
- Doctors use EKGs to detect and study many heart problems, such as heart attacks, arrhythmias, and heart failure. The test's results also can suggest other disorders that affect heart function


Name:
[redacted]
ID:
[redacted]
Patient ID:
Incident:
Age: 26
Sex:
12-Lead 2
PR 0.138s
QT/QTc
P-QRS-T Axes
aVR
HR 62 bpm
14:37:18
QRS 0.112s
0.398s/0.395s
27° 88° 49°
• Normal ECG **Unconfirmed**
• Normal sinus rhythm
I
II
III
aVL
aVF
V1
V2
V3
V4
V5
V6
x1.0 .05-150Hz 25mm/sec
[redacted]

Electrical System of the Heart



Impulse Conduction & the ECG

Sinoatrial node

↓

AV node

↓

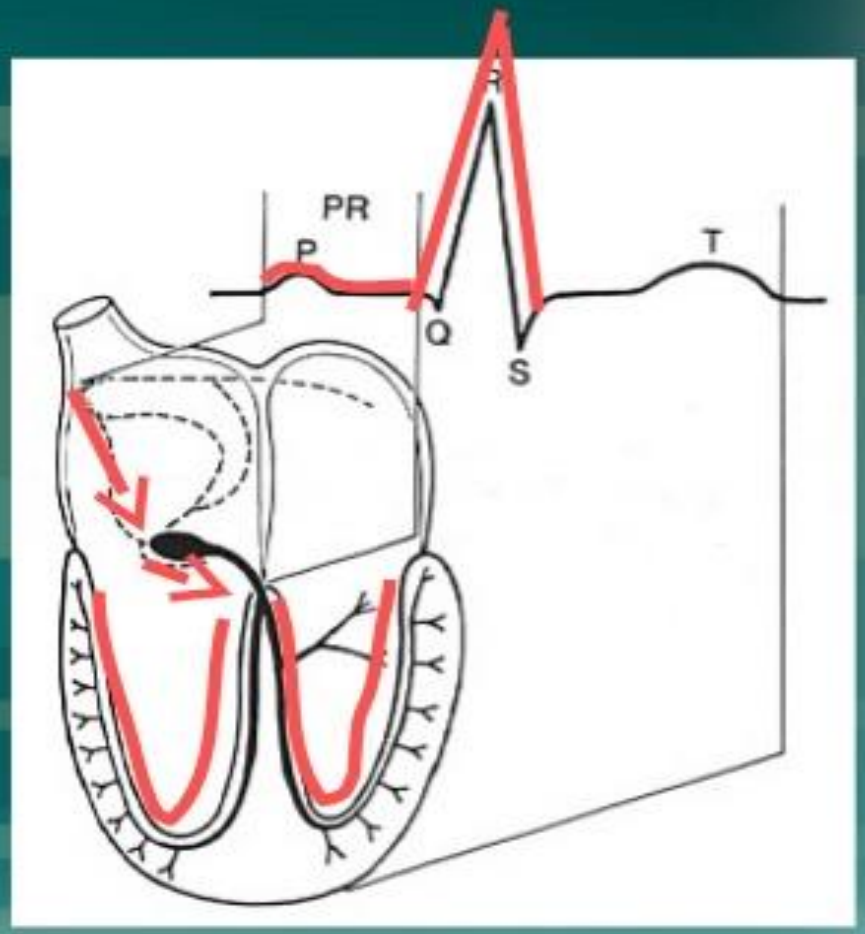
Bundle of His

↓

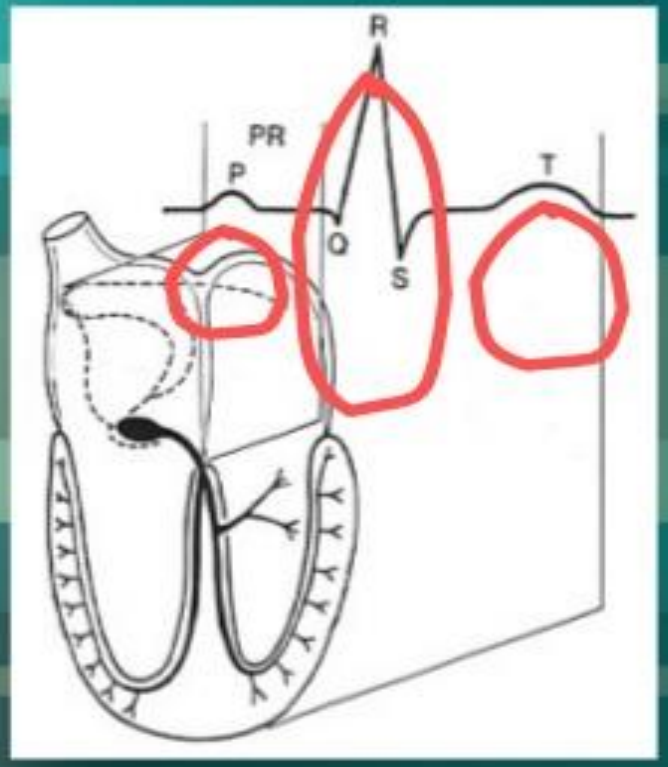
Bundle Branches

↓

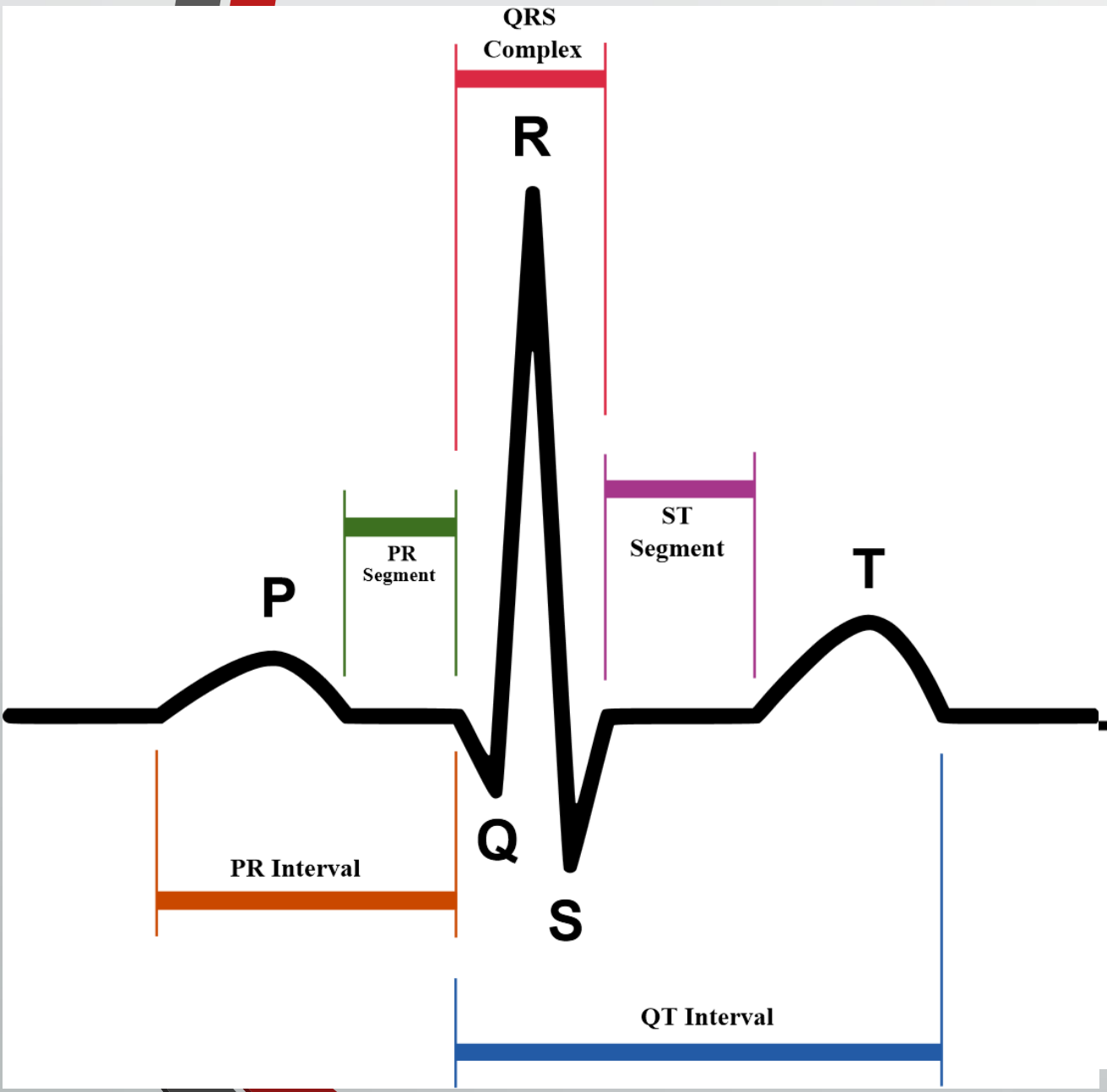
Purkinje fibers

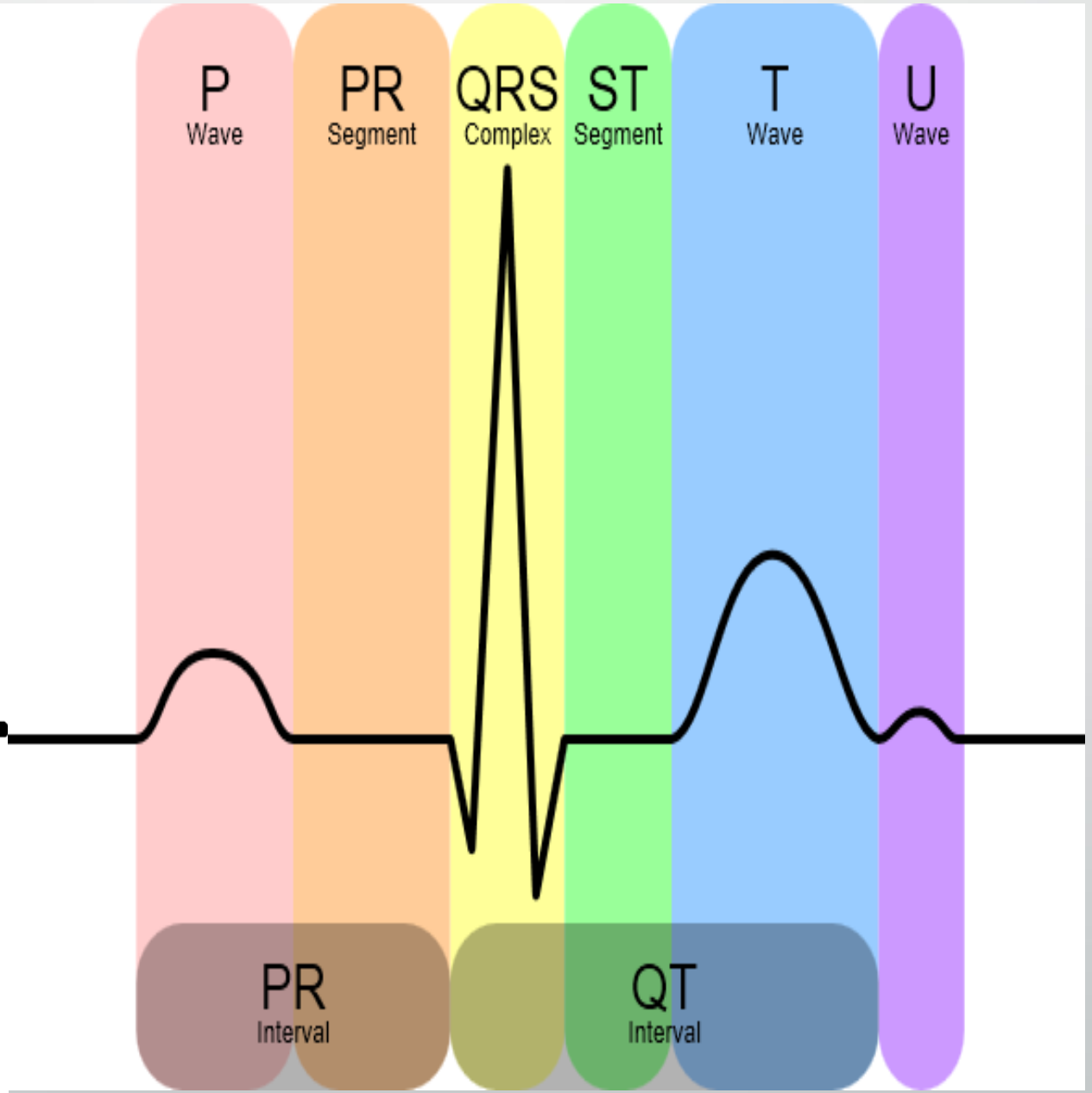


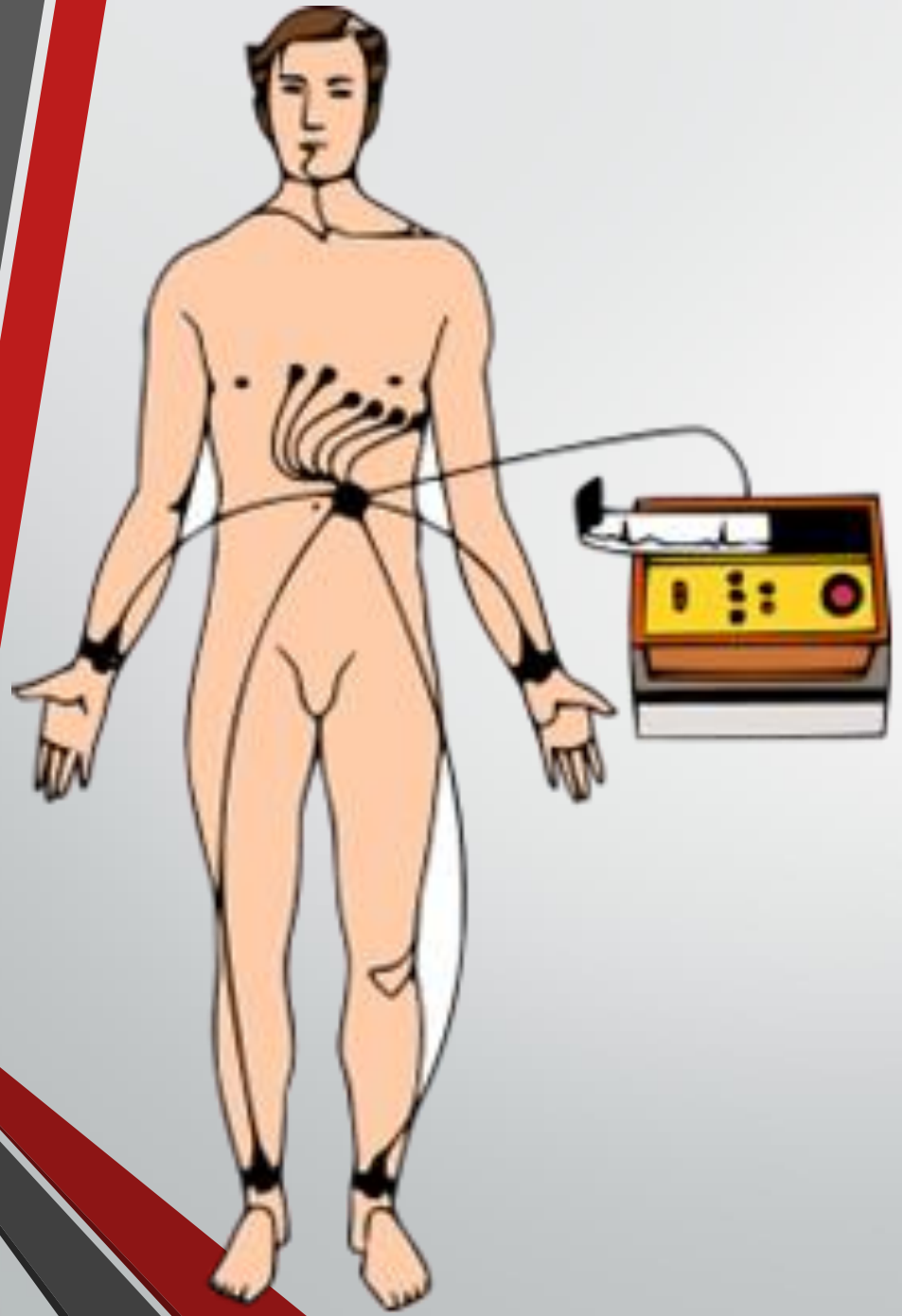
The "PQRST"



- P wave - Atrial depolarization
- QRS - Ventricular depolarization
- T wave - Ventricular repolarization


QRS
Complex
R
ST
Segment
PR
Segment
P
T
Q
S
PR Interval
QT Interval

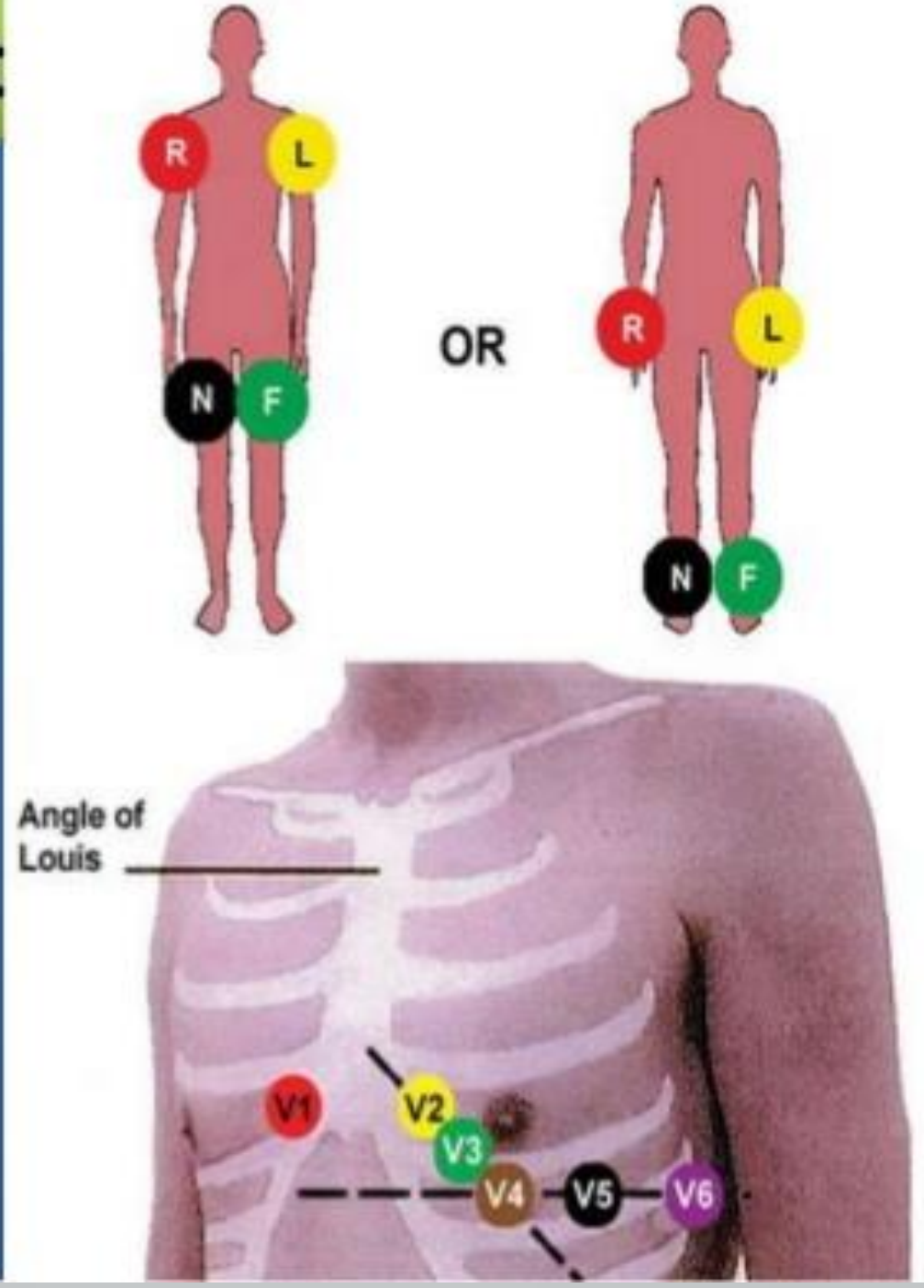

P
Wave
PR
Segment
QRS
Complex
ST
Segment
T
Wave
U
Wave
PR
Interval
QT
Interval



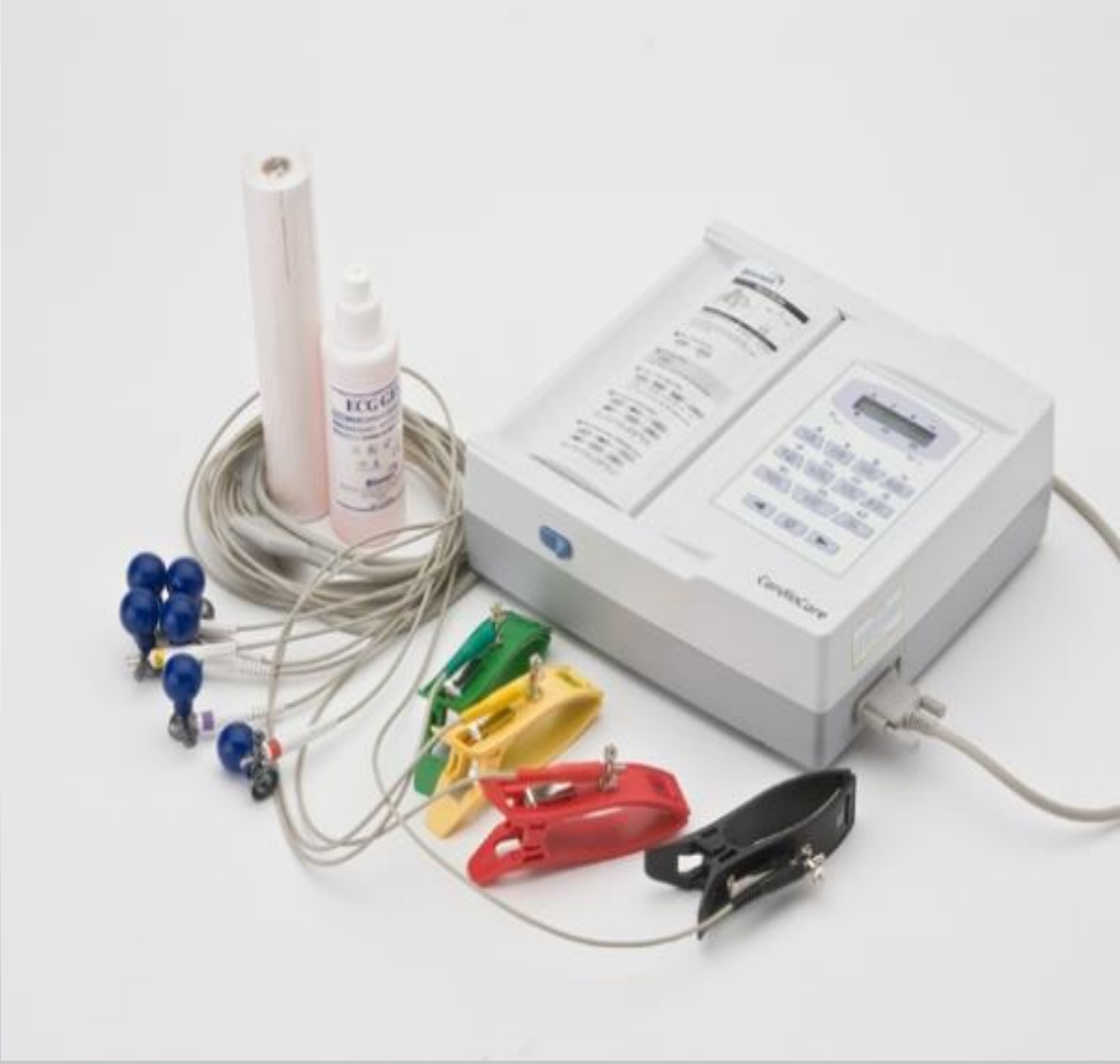
- the word *lead* may refer to the tracing of the voltage difference between two of the electrodes and is what is actually produced by the ECG recorder.
- Each will have a specific name. For example **"lead I"** is the voltage **between** the **right arm electrode and the left arm electrode**, whereas **"Lead II"** is the voltage between the **right arm and the feet**.

Limb Lead Placement

- Connect the lead wires to the electrodes. The tip of each lead wire is lettered and color-coded for easy identification.
- The red or RA lead wire goes to the right arm
- The yellow or LA lead wire goes to left arm
- The black or N/ RL lead wire goes to right leg
- The green or LL lead wire goes to left leg

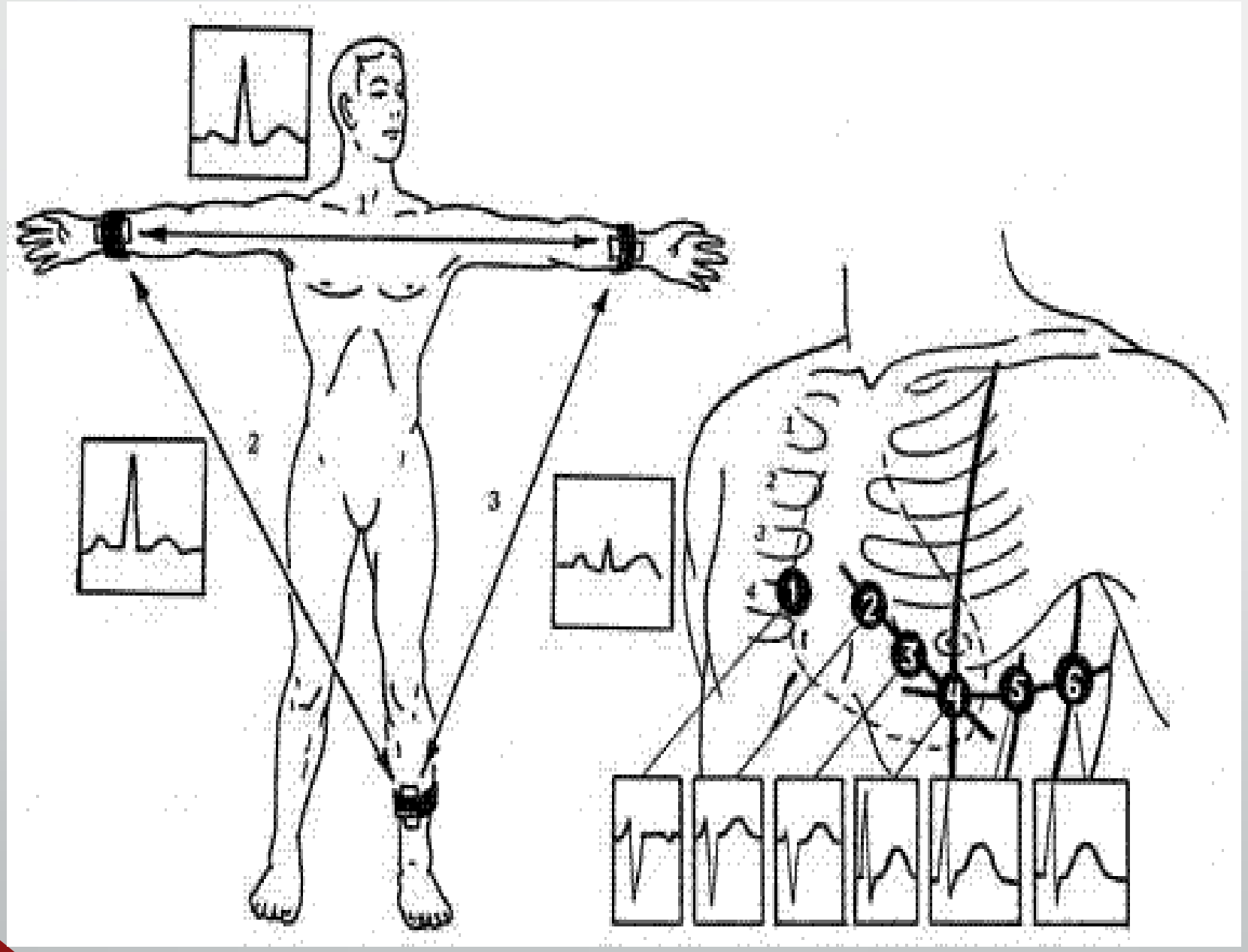


Electrocardiograph (ECG) - a device to record changes of the electric field potential difference (biopotential) of the heart.

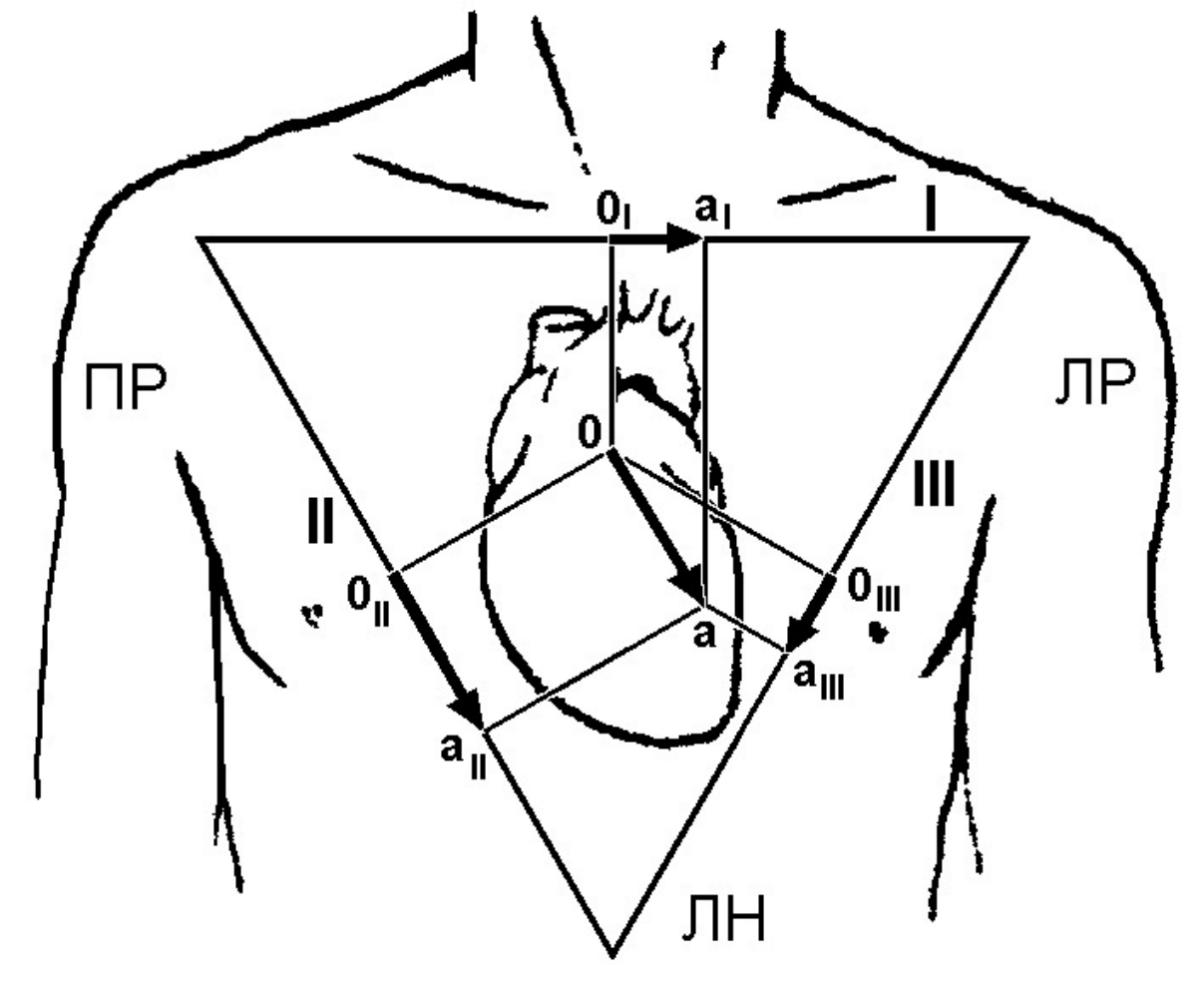


Einthoven theory - theory of the formation of the electrocardiogram, according to which the heart is regarded as infinitely small dipole, located in the center of the triangle Einthoven and continuously changing the magnitude and direction of the vector of the electromotive force; the projection of each of the parties to determine the shape of a triangle in three standard electrocardiogram leads

Einthoven standard leads



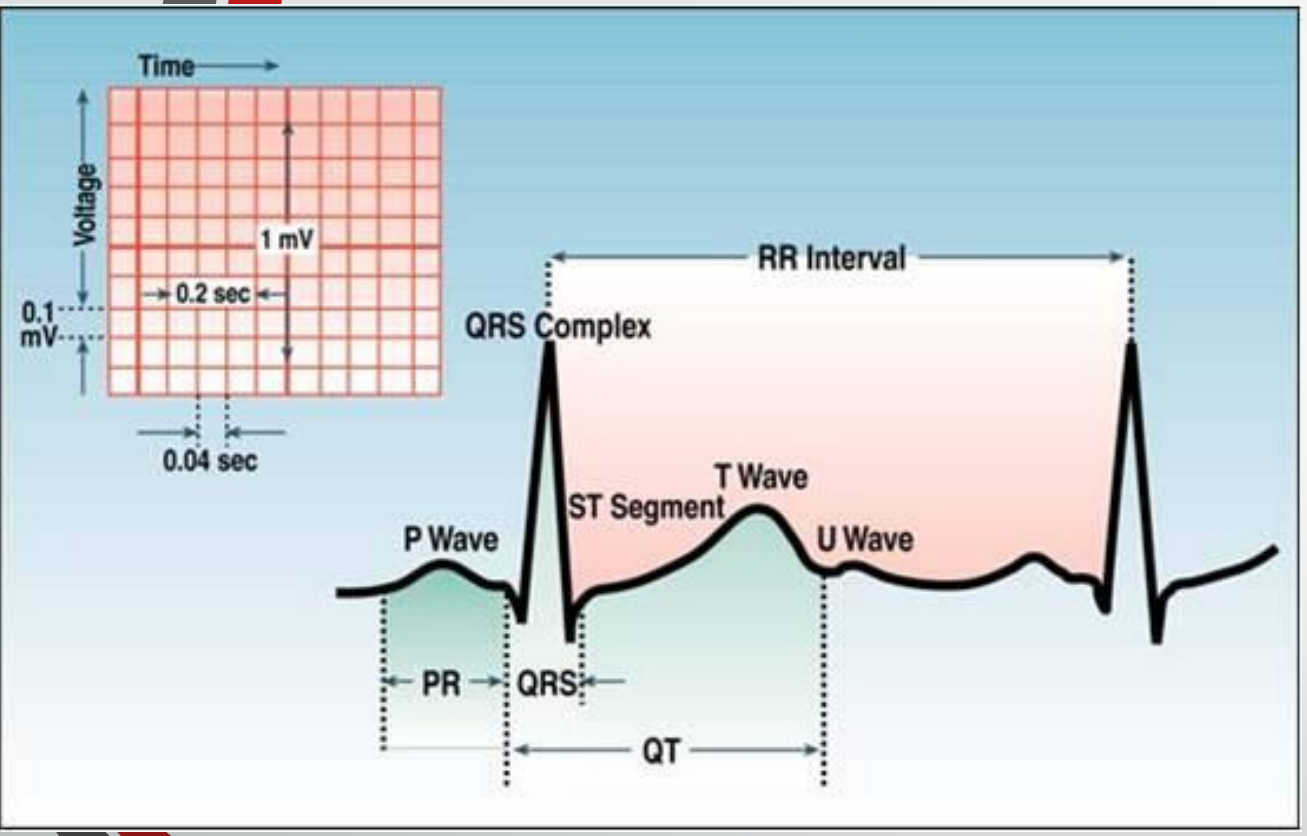
Cardiac axis



- When you average all electrical signals from the heart, you can indicate the direction of the average electrical depolarization with an arrow (vector). This is the heart axis. A change of the heart axis or an extreme deviation can be an indication of pathology.

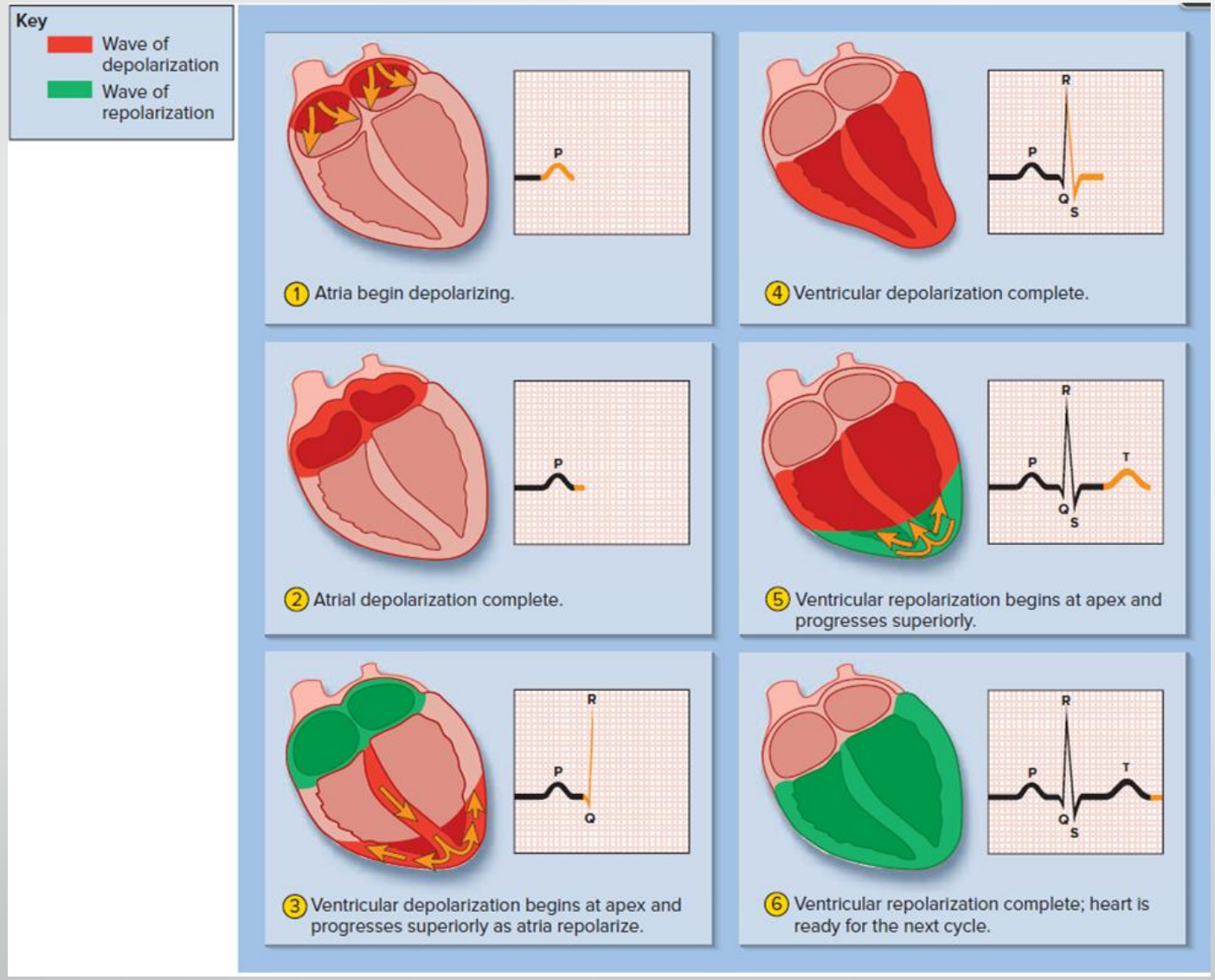
Electrocardiogram

ECG Waves and Intervals:

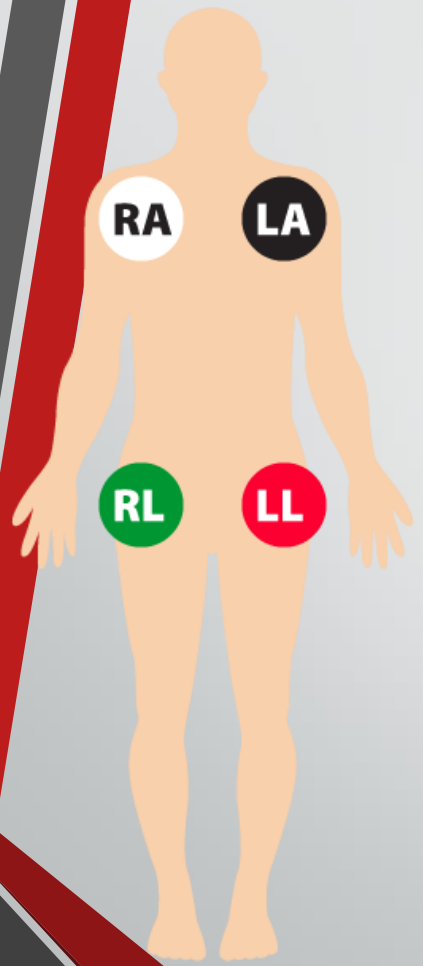


- **P wave:** the sequential activation (depolarization) of the right and left atria
- **QRS complex:** right and left ventricular depolarization (normally the ventricles are activated simultaneously)
- **ST-T wave:** ventricular repolarization
- **U wave:** origin for this wave is not clear - but probably represents "afterdepolarizations" in the ventricles
- **PR interval:** time interval from onset of atrial depolarization (P wave) to onset of ventricular depolarization (QRS complex)
- **QRS duration:** duration of ventricular muscle depolarization
- **QT interval:** duration of ventricular depolarization and repolarization
- **RR interval:** duration of ventricular cardiac cycle (an indicator of ventricular rate)
- **PP interval:** duration of atrial cycle (an indicator of atrial rate)

Electrocardiogram - waveform (one cardiac cycle)



Electrocardiogram - Lead Placement Diagrams



RA Right Arm

LA Left Arm

LL Left Leg

RL Right Leg

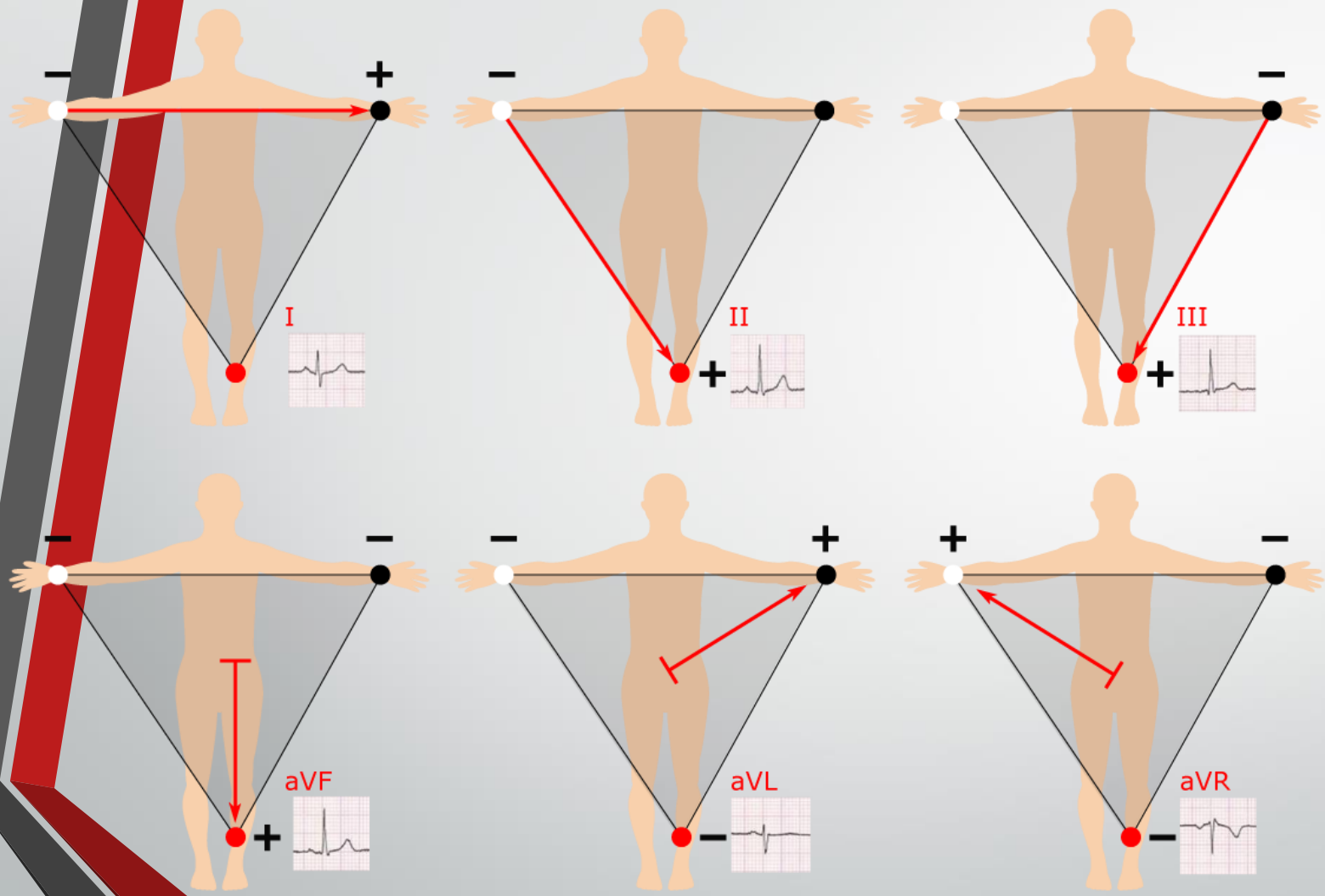
» **RA (Right Arm)** - Anywhere between the right shoulder and right elbow

» **RL (Right Leg)** - Anywhere below the right torso and above the right ankle

» **LA (Left Arm)** - Anywhere between the left shoulder and the left elbow

» **LL (Left Leg)** - Anywhere below the left torso and above the left ankle

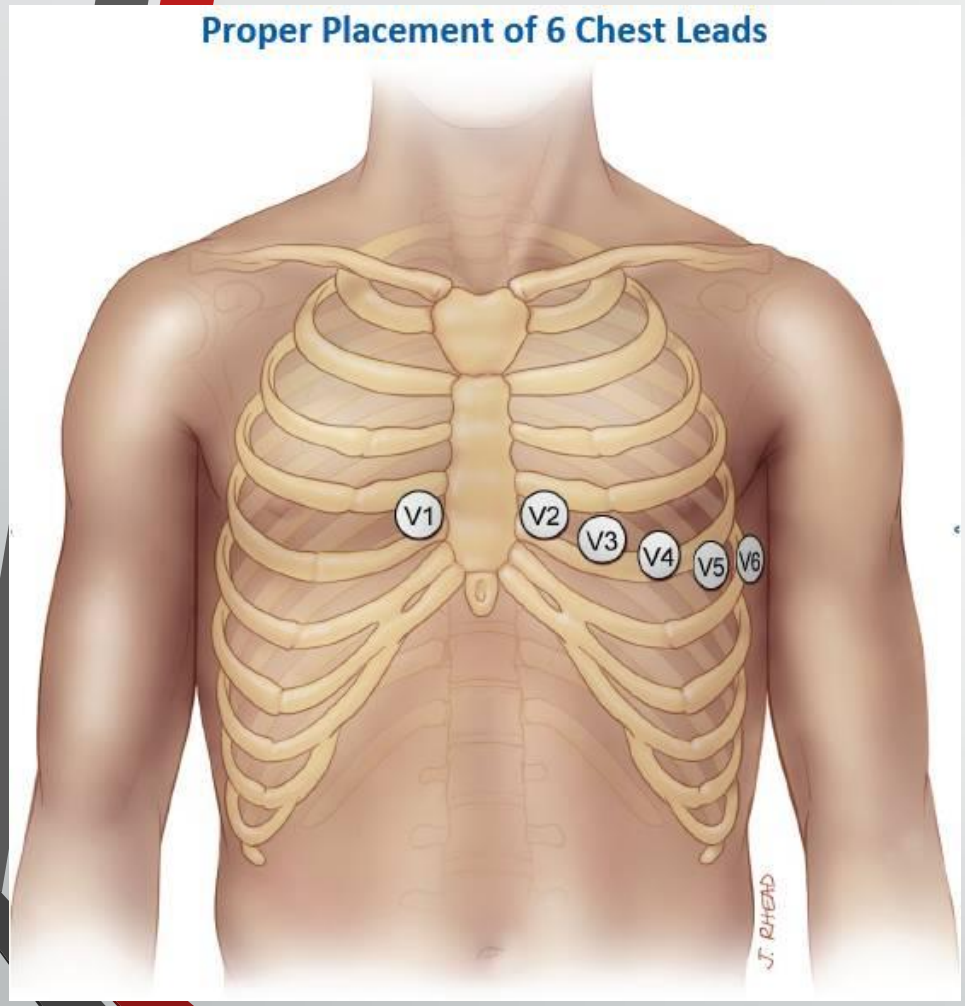
Einthoven's Triangle



The principle behind Einthoven's triangle describes how electrodes RA, LA and LL do not only record the electrical activity of the heart in relation to themselves through the aVR, aVL and aVF leads.
They also correspond with each other to form leads I (RA to LA), II (RA to LL) and III (LL to LA).

Keep in mind that RL is neutral (also known as point zero where the electrical current is measured).
RL doesn't come up in ECG readings, and is considered as a grounding lead that helps minimize ECG artifact.

Electrocardiogram - Lead Placement Diagrams



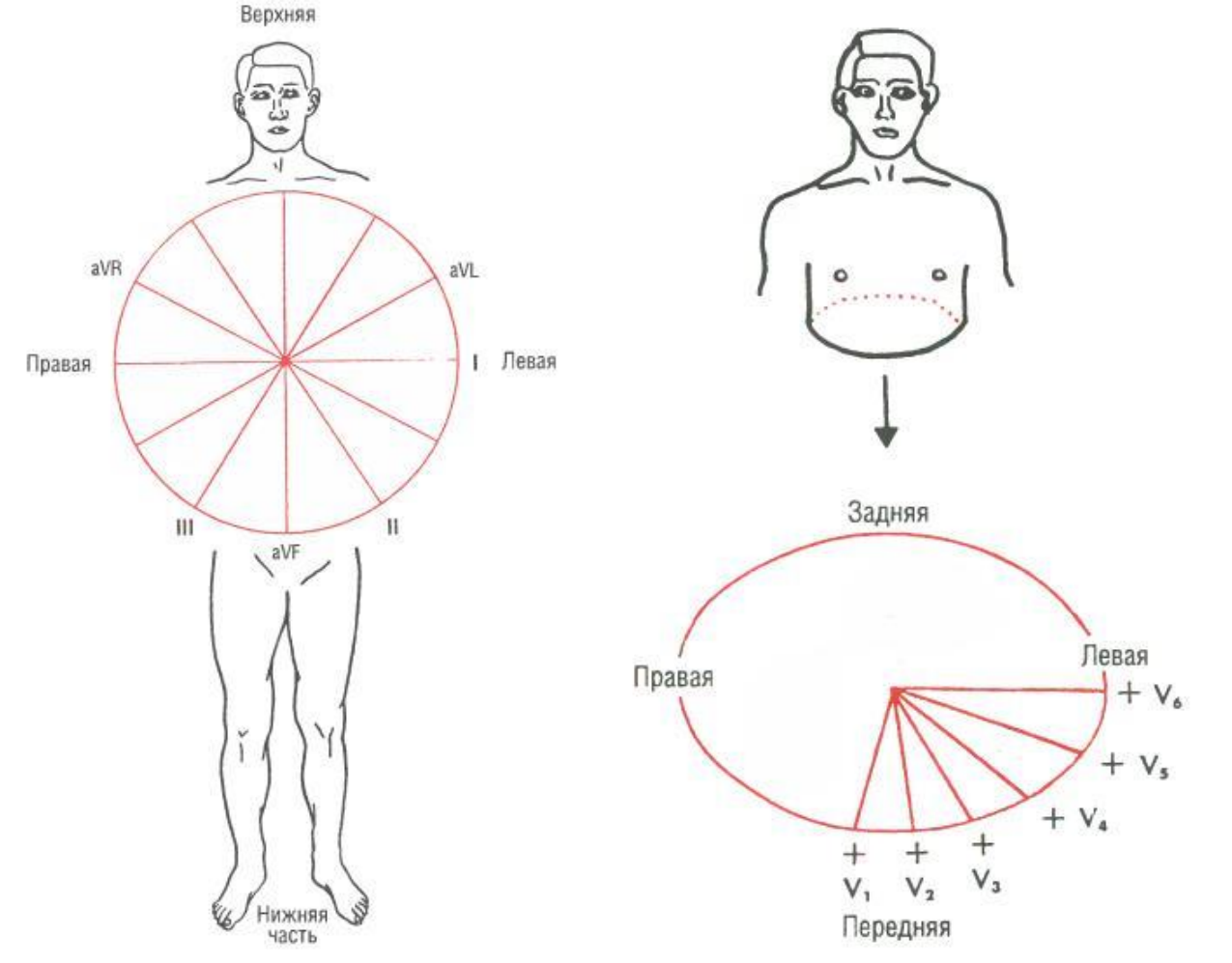
V1: right 4th intercostal space
V2: left 4th intercostal space
V3: halfway between V2 and V4
V4: left 5th intercostal space, mid-clavicular line
V5: horizontal to V4, anterior axillary line
V6: horizontal to V5, mid-axillary line

By using 6 chest electrodes, you get 6 transverse leads that provide information about the heart's horizontal plane: V1, V2, V3, V4, V5, and V6. Like the augmented leads, the transverse leads are unipolar and requires only a positive electrode. The negative pole of all 6 leads is found at the center of the heart. This is calculated with the ECG.

Unipolar (+) chest leads (horizontal plane):

- Leads V1, V2, V3: (Posterior Anterior)
- Leads V4, V5, V6: (Right Left, or lateral)

Electrocardiogram - Lead Placement Diagrams



A lead is a glimpse of the electrical activity of the heart from a particular angle.

Put simply, a lead is like a perspective. In **12-lead ECG**, there are 10 electrodes providing 12 perspectives of the heart's activity using different angles through two electrical planes - vertical and horizontal planes.

Vertical plane (Frontal Leads):

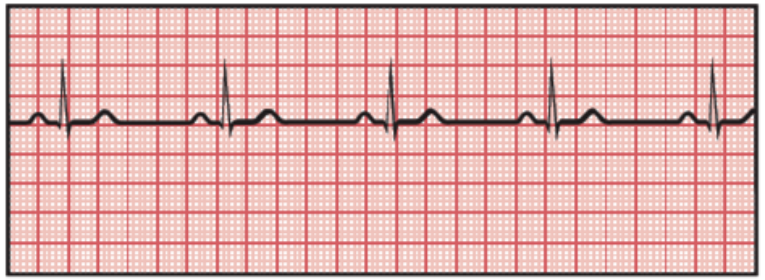
By using 4 limb electrodes, you get 6 frontal leads that provide information about the heart's vertical plane:

- Lead I
- Lead II
- Lead III
- Augmented Vector Right (aVR)
- Augmented Vector Left (aVL)
- Augmented vector foot (aVF)

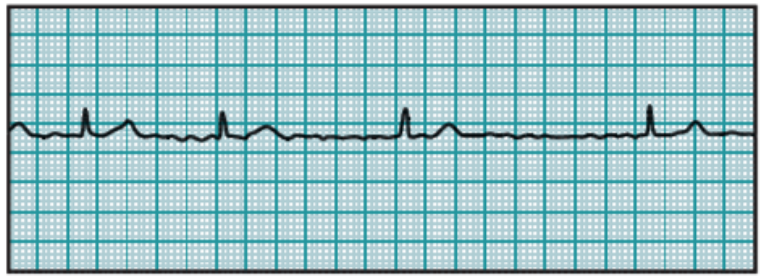
Leads I, II, and III require a negative and positive electrode (bipolarity) for monitoring.

On the other hand, the augmented **leads-aVR, aVL, and aVF** are unipolar and requires only a positive electrode for monitoring.

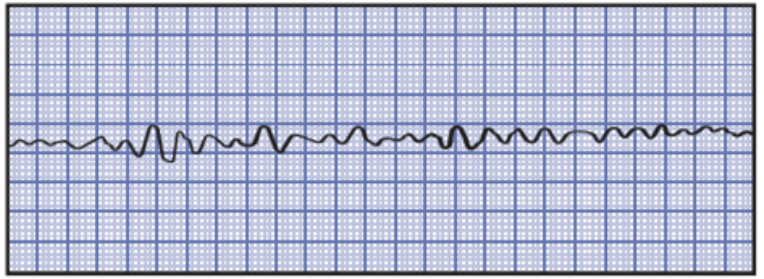
Normal and pathological electrocardiograms



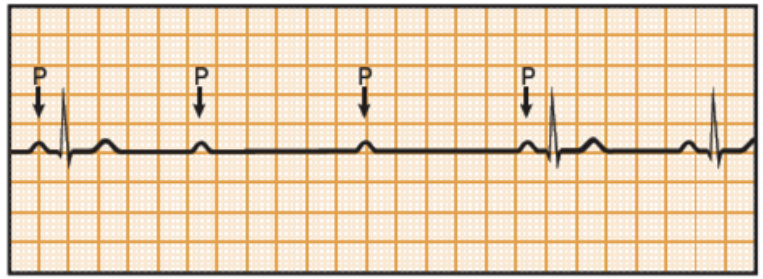
(a) Sinus rhythm (normal)



(c) Atrial fibrillation

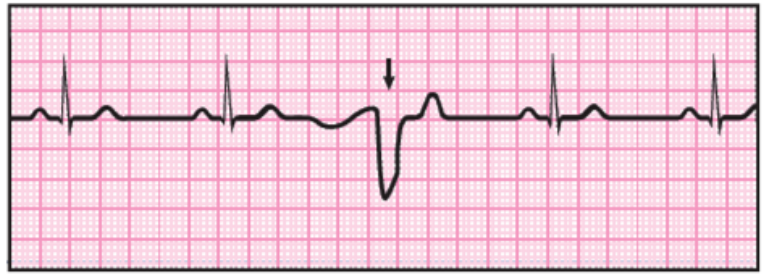


(b) Ventricular fibrillation



(d) Heart block

FIGURE 19.17 Normal and Pathological Electrocardiograms. (a) Normal sinus rhythm. (b) Ventricular fibrillation, with grossly irregular waves of depolarization, as seen in a heart attack (myocardial infarction). (c) Atrial fibrillation; between heartbeats, the atria exhibit weak, chaotic, high-frequency depolarizations instead of normal P waves. (d) Heart block, in which some atrial depolarizations (P waves) are not conducted to the ventricles and not followed by ventricular QRS waves. (e) Premature ventricular contraction, or extrasystole (at arrow); note the absence of a P wave, the inverted QRS complex, and the misshapen QRS and elevated T.



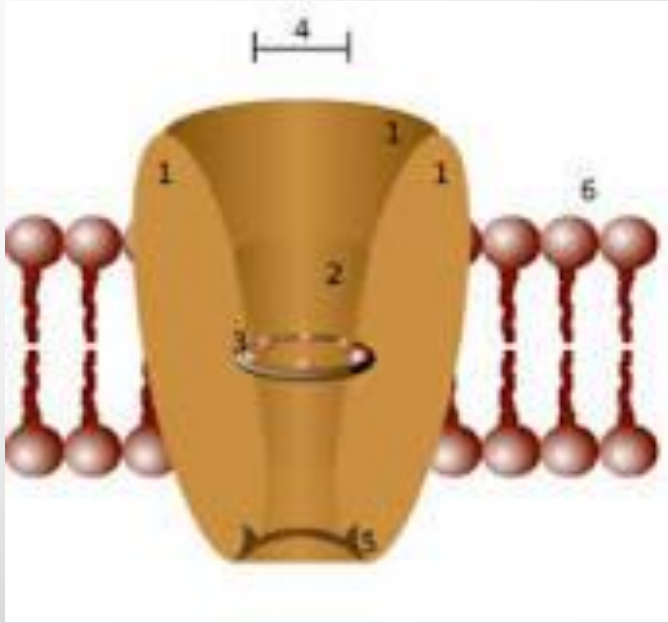
(e) Premature ventricular contraction

Ion channels

Two main forces drive ions across the cell membrane:

- ***Chemical potential:*** an ion will move down its *concentration gradient.*
- ***Electrical potential:*** an ion will move away from ions/molecules of like charge.

Ion channels help maintain ionic concentration gradients and charge differentials between the inside and outside of the cardiomyocytes.



Properties of cardiac ion channels

- **Selectivity***:* they are only permeable to a single type of ion based on their physical configuration.
- **Voltage-sensitive gating**: a specific transmembrane potential (TMP) range is required for a particular channel to be in open configuration; at all TMPs outside this range, the channel will be closed and impermeable to ions. Therefore, specific channels open and close as the TMP changes during cell depolarization and repolarization, allowing the passage of different ions at different times.
- **Time-dependence**: *some* ion channels (importantly, fast Na+ channels) are configured to close a fraction of a second after opening; they cannot be opened again until the TMP is back to resting levels, thereby preventing further excessive influx.

Cardiac action potential

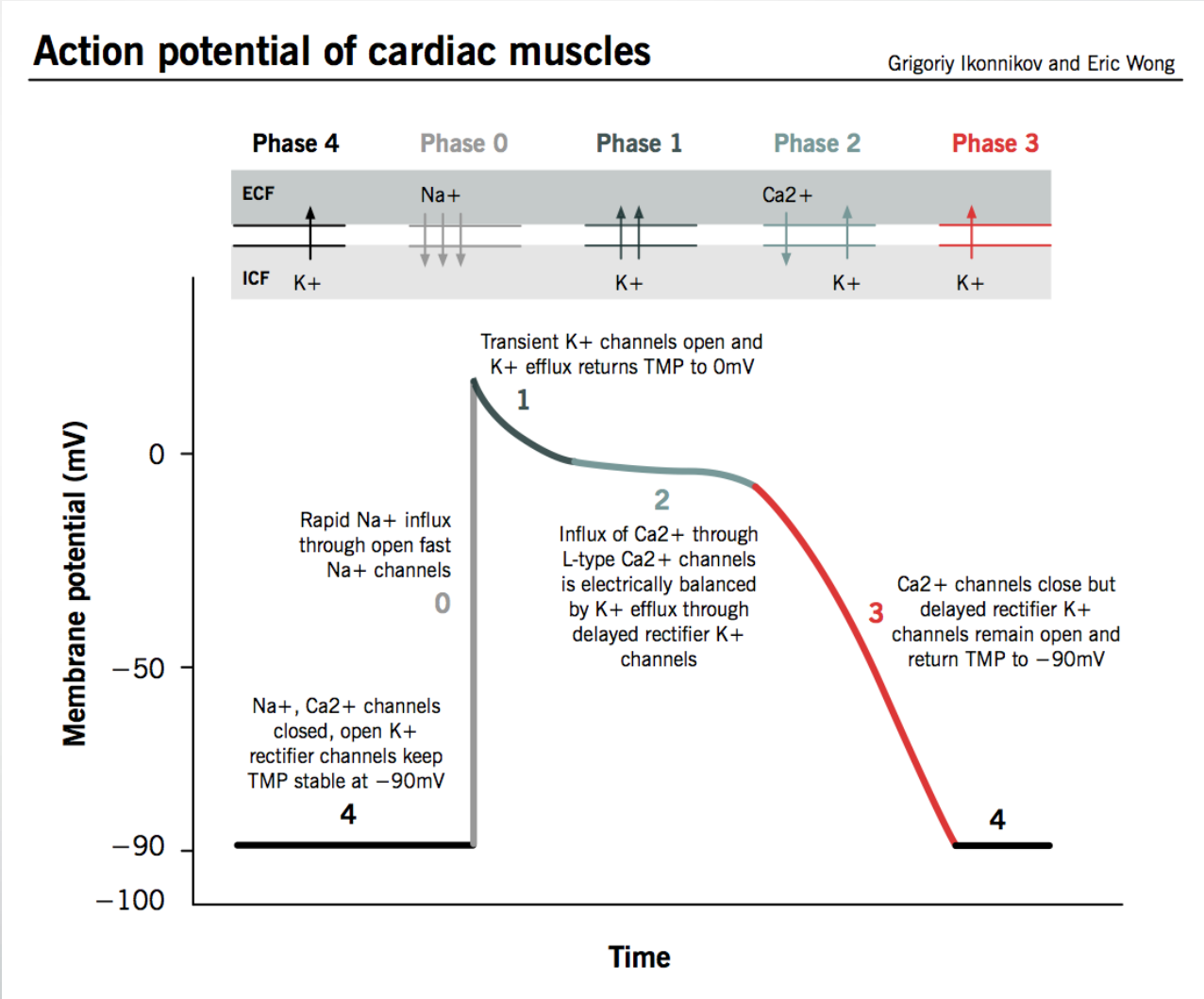
The action potential in typical cardiomyocytes is composed of 5 phases (0-4), beginning and ending with phase 4.

Phase 4: The resting phase

- The resting potential in a cardiomyocyte is −90 mV due to a constant outward leak of K+ through *inward rectifier channels.*
- Na+ and Ca2+ channels are closed at resting TMP.

Phase 0: Depolarization

- An action potential triggered in a neighbouring cardiomyocyte or pacemaker cell causes the TMP to rise above −90 mV.
- Fast Na+ channels start to open one by one and Na+ leaks into the cell, further raising the TMP.
- TMP approaches −70mV, the **threshold potential** in cardiomyocytes, i.e. the point at which enough fast Na+ channels have opened to generate a self-sustaining inward Na+ current.
- The large Na+ current rapidly depolarizes the TMP to 0 mV and slightly *above* 0 mV for a transient period of time called the **overshoot**; fast Na+ channels close (recall that fast Na+ channels are *time-dependent*).
- L-type ("long-opening") Ca2+ channels open when the TMP is *greater than* −40 mV and cause a small but steady influx of Ca2+ down its concentration gradient.



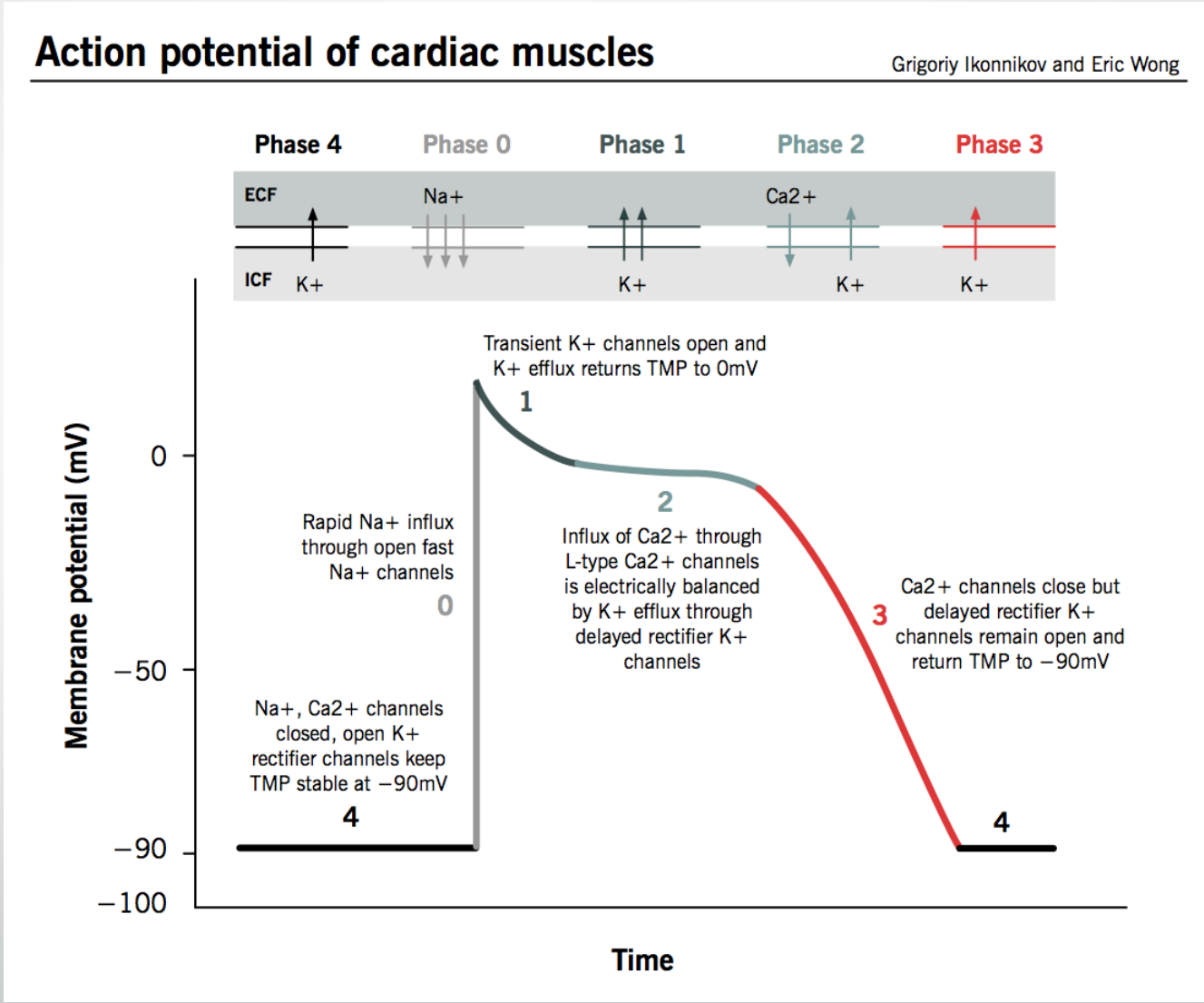
Cardiac action potential

Phase 1: Early repolarization

- TMP is now slightly positive.
- Some K+ channels open briefly and an outward flow of K+ returns the TMP to approximately 0 mV.

Phase 2: The plateau phase

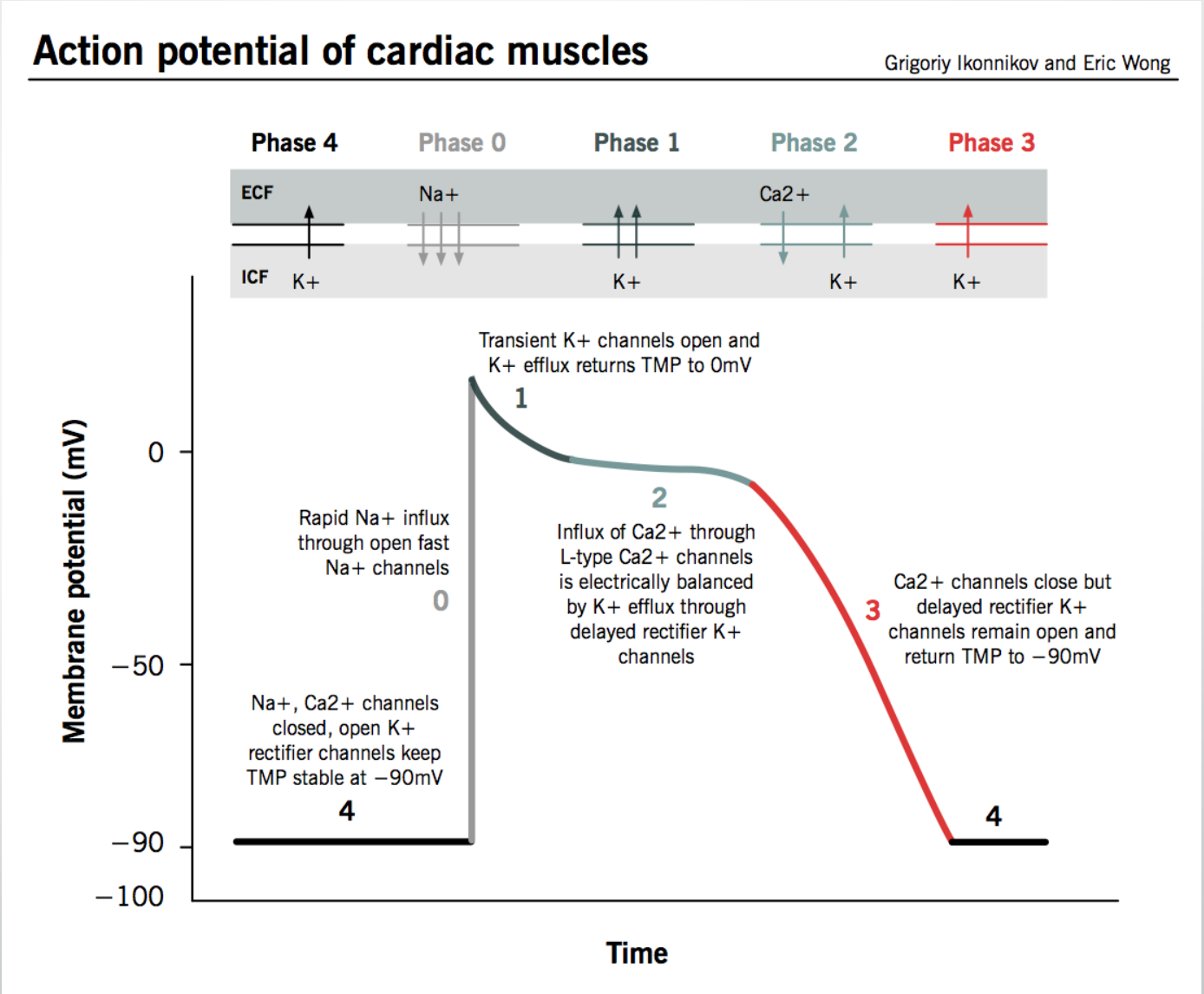
- L-type Ca2+ channels are still open and there is a small, constant inward current of Ca2+. This becomes significant in the *excitation-contraction coupling* process described below.
- K+ leaks out down its concentration gradient through *delayed rectifier* K+ channels.
- These two counter currents are electrically balanced, and the TMP is maintained at a *plateau* just below 0 mV throughout phase 2.



Cardiac action potential

Phase 3: Repolarization

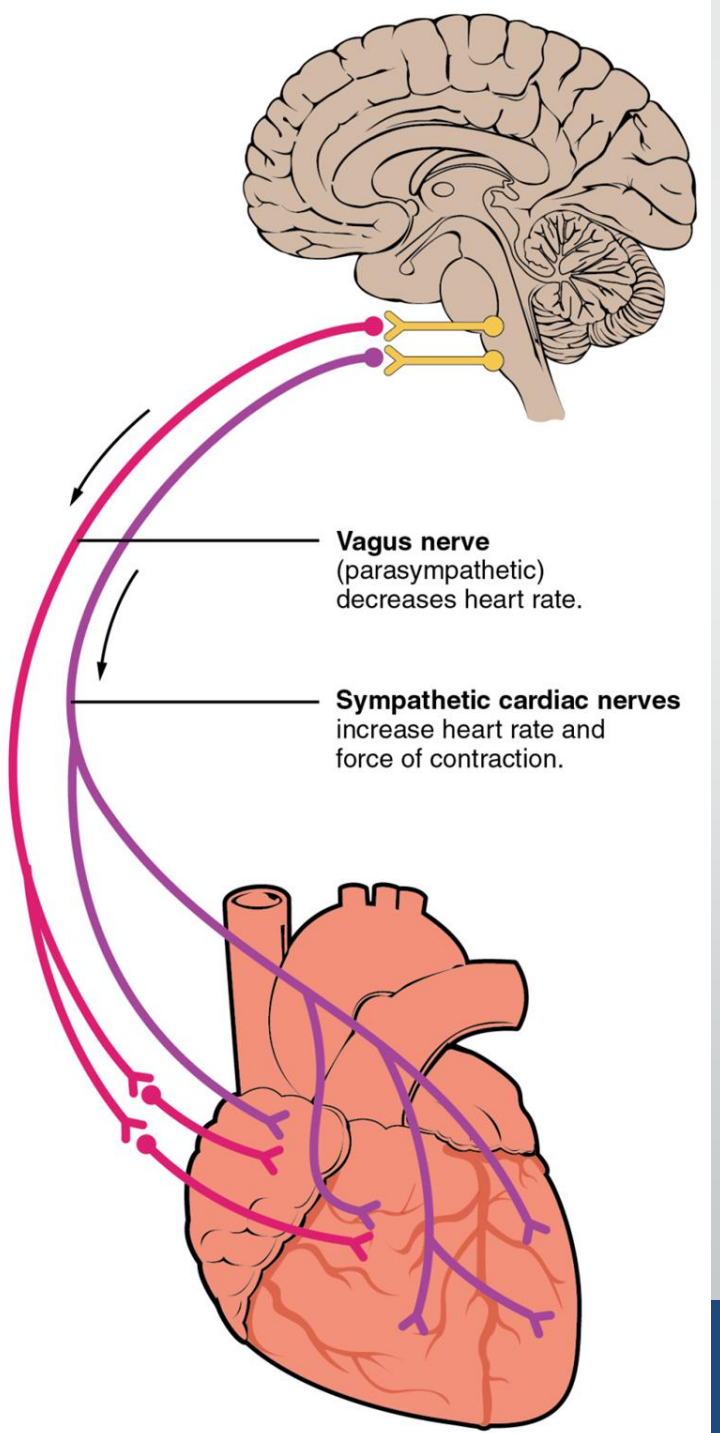
- Ca2+ channels are gradually inactivated.
- Persistent outflow of K+, now exceeding Ca2+ inflow, brings TMP back towards resting potential of −90 mV to prepare the cell for a new cycle of depolarization.
- Normal transmembrane ionic concentration gradients are restored by returning Na+ and Ca2+ ions to the extracellular environment, and K+ ions to the cell interior. The pumps involved include the sarcolemmal *Na+-Ca2+ exchanger*, *Ca2+-ATPase* and *Na+-K+-ATPase*.



Nerve supply to the heart

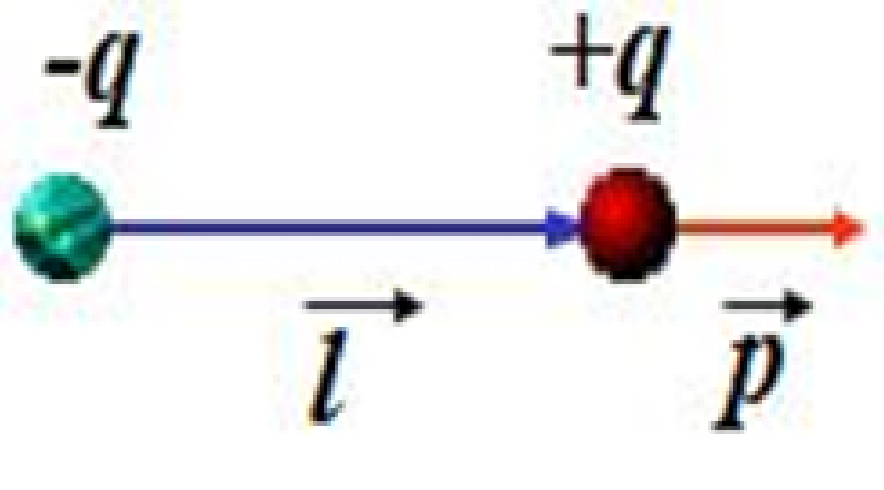
The **sympathetic nervous system** acts on the sinoatrial node, speeding up the depolarisation rate, and therefore increasing the heart rate.

The **parasympathetic system** works in reverse in order to slow the heart rate down. The heart itself has a natural pacemaker, the sinoatrial node, which does not need a nervous supply to function. If you sever all the nerves to the heart, then it will continue to beat. In fact, it will beat faster than normal, since there is normally a parasympathetic supply slowing the heart down.



Electric dipole - a system of two point charges + q and -q, rigidly connected to each other and spaced at a distance l from each other. The displacement of both charges characterize vector directed from a negative to a positive charge. The dipole moment is characterized by an electric dipole

$$P=ql$$



$$\varphi = k\frac{q}{r}$$

$$\varphi = \frac{1}{4\pi\varepsilon_0}\frac{p\cos\alpha}{r^2}$$

The potential of the electric field of a point charge

The electric field strength

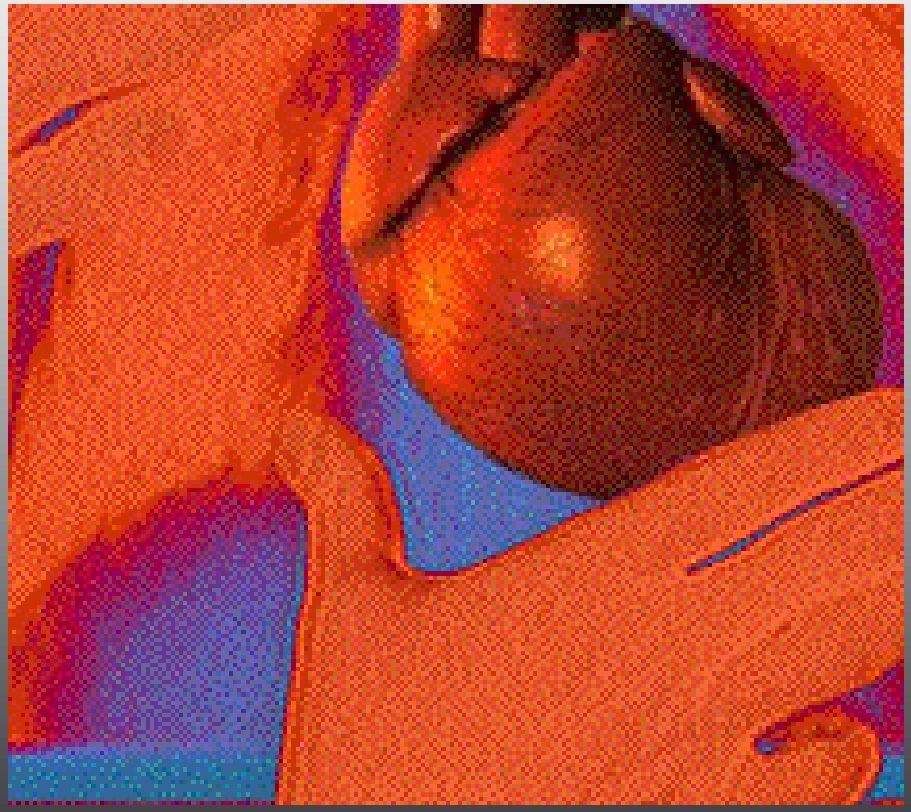
$$E = \frac{F}{q}$$

Where: E-the electric field strength

F-Coulomb force

q- charge

Haemodynamic regularities of the movement of blood. Rheological properties of blood.



OBJECTIVES:

- Distribution of blood volume, flow, pressure, vessel resistance throughout the circulatory system.
- Discuss Poiseuille's Law and the effects of radius, length, viscosity and resistance on blood flow.
- Limitations of applying classical hemodynamics to blood.

HEMODYNAMICS

The Physical properties of blood, blood vessels and the heart and their interactions

Consists of :

Pressure = Mean Arterial Pressure (MAP)

Flow = Cardiac Output (CO)

Resistance = Total peripheral resistance (TPR)

$$\text{Flow} = \frac{\text{Pressure Difference}}{\text{Resistance}}$$

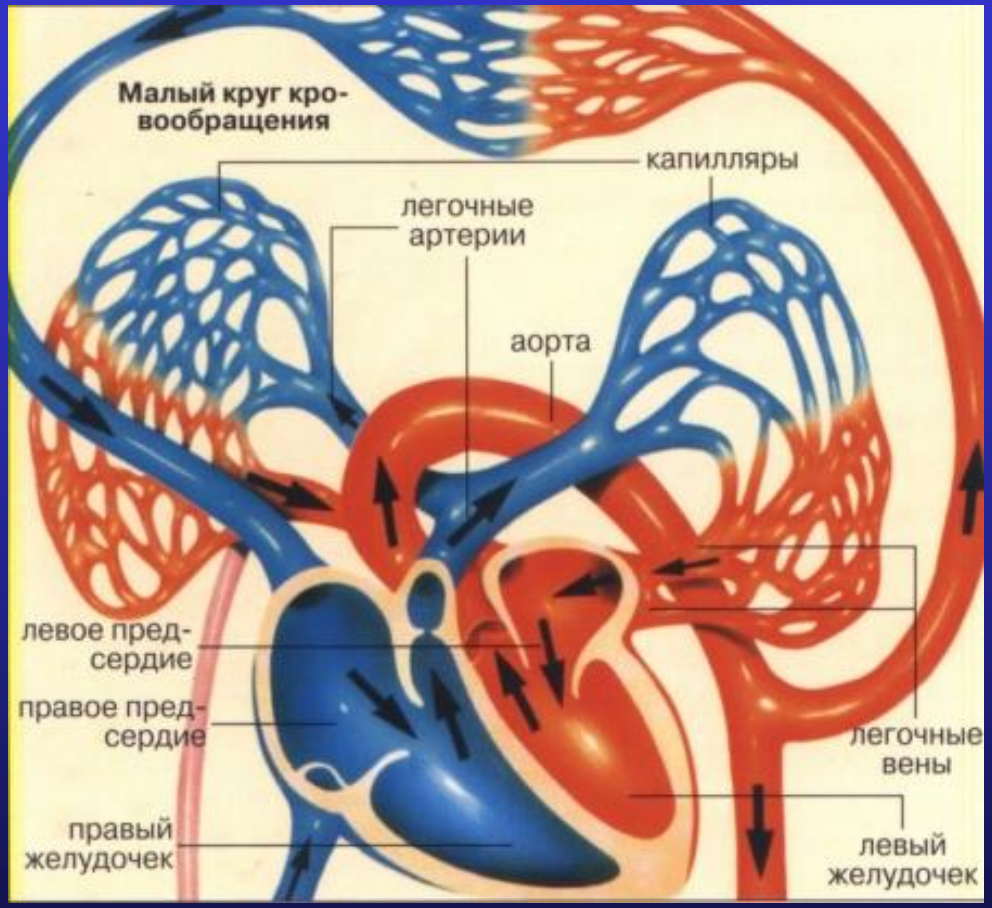
(Ohm's Law)

Circulatory System

- **Heart:**

  Has 2 collecting chambers - (Left, Right Atria)

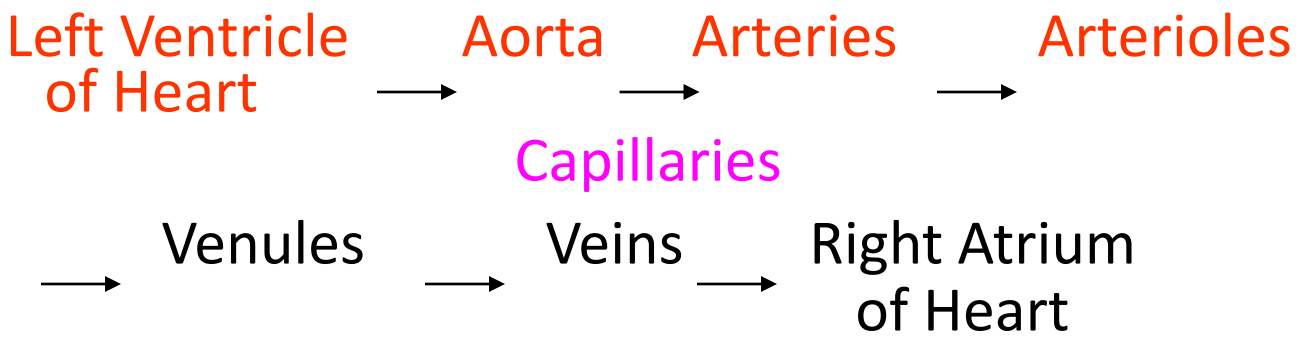
  Has 2 Pumping chambers - (Left, Right Ventricles)


Малый круг кро-
вообращения
капилляры
легочные
артерии
аорта
левое пред-
сердие
правое пред-
сердие
легочные
вены
правый
желудочек
левый
желудочек

Blood Vessels

- Arteries
- Capillaries
- Veins

Systemic Pathway:



Blood

- Composition:
  - Approx 45% by Vol. Solid Components
    - » Red Blood Cells (12μm x 2 μm)
    - » White Cells
    - » Platelets
  - Approx 55% Liquid (plasma)
    - » 91.5% of which is water
    - » 7% plasma proteins
    - » 1.5% other solutes

Blood Functions

- Transportation

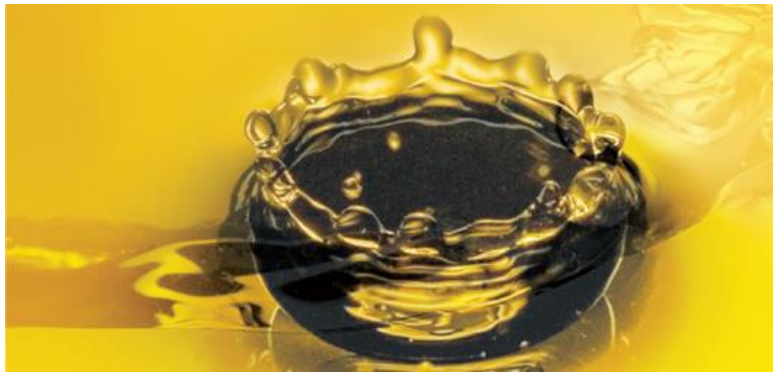
  of blood gases, nutrients, wastes

- Homeostasis (regulation)

  of Ph, Body Temp, water content

- Protection

Viscosity



- Viscosity is the fluid property that measures the resistance of the fluid to deforming due to a shear force.
- For most fluids, temperature and viscosity are inversely proportional.

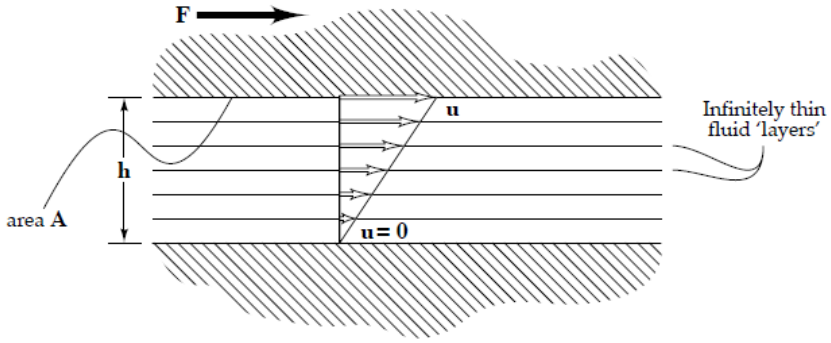
- An ideal fluid is one that is incompressible and has no viscosity.

Viscosity

- Viscosity is a quantitative measure of a fluid's resistance to flow.

Dynamic (or Absolute) Viscosity:

- The dynamic viscosity(η) of a fluid is a measure of the resistance it offers to relative shearing motion.



Kinematic Viscosity:

- It is defined as the ratio of absolute viscosity to the density of fluid.

Relative viscosity:

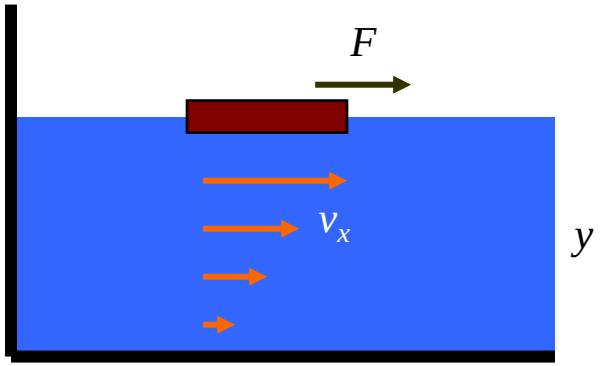
Is the relation of the solution viscosity $\boldsymbol{\eta}$ to the viscosity of the solvent "standard" η_0.

$$\eta_{rel} = \eta/\eta_0$$

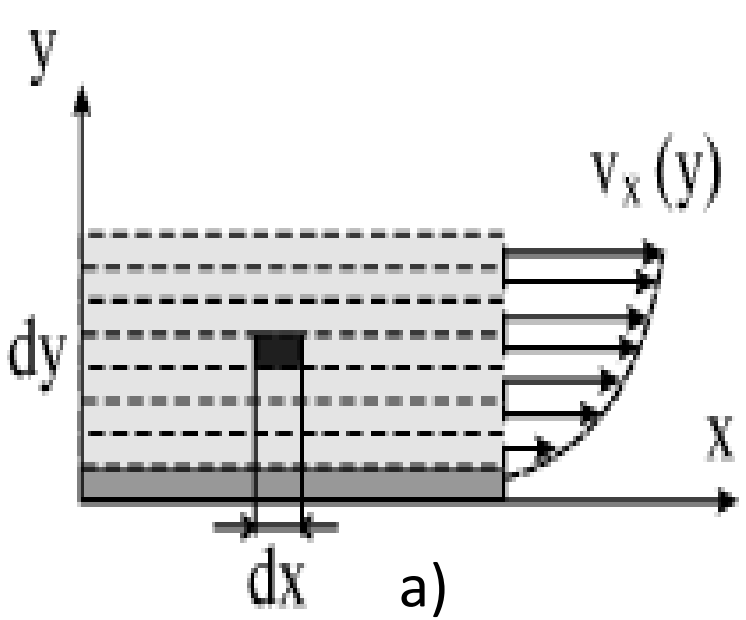
Newton's Law

- This is the law of viscosity.
  - S is the area of the solid sliding on the fluid

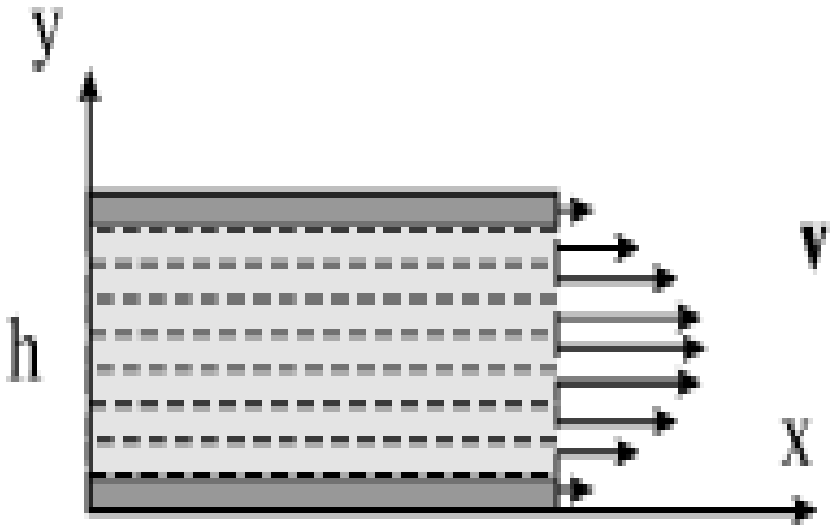
- The constant η is the *dynamic viscosity* and depends on the type of fluid.



$$F = \eta \cdot \left(\frac{dv}{dx}\right) \cdot S$$



a)



b)

RHEOLOGY

- Science describing the flow and deformation of matter under stress.

- Rheo = the flow

- Viscosity (η) is the resistance of a fluid material to flow under stress. The higher the viscosity, the greater the resistance.

Important for:

– Formulation of medicinal and cosmetic creams, pastes and lotion.

– Formulation of emulsion, suspension, suppositories and tablet coatings.

– Fluidity of solutions for injection.

– In mixing and flow of materials, their packaging into containers, their removal prior to use, whether by pouring from a bottle, extrusion from a tube, or passage through a syringe needle.

– Can affect patient acceptability, physical stability, and even biological availability.

Classification of Rheological Systems:

1. Newtonian System
2. Non-Newtonian System

Newtonian Fluids

- Newtonian fluids are those whose viscosity is independent of shear rate.
- The viscosity of these materials will remain a constant no matter how fast they are forced to flow through a pipe or channel.
- Examples of Newtonian fluids would include water, organic solvents, and honey.

Newtonian Fluids

water

ethyl alcohol

air

Non-Newtonian Fluids

blood

toothpaste

ketchup

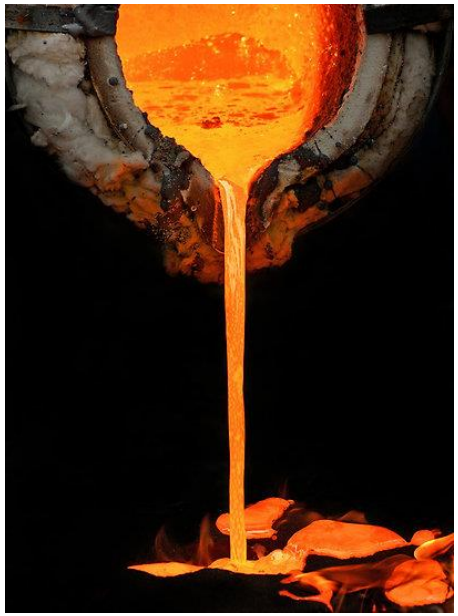
Non-Newtonian Fluids

grease

cake batter

polymer melt

Non-Newtonian Fluids



molten metal

whipped cream

paint

Non-Newtonian Fluids

Why are these fluids non-Newtonian?

Non-Newtonian behavior is frequently associated with complex internal structure:

- The fluid may have large complex molecules (like a polymer), or
- The fluid may be a heterogeneous solution (like a suspension)...

Non-Newtonian Fluids

Why are these fluids non-Newtonian?

Fluid systems may be non-ideal in two ways:

1. The viscosity may depend on shear rate
2. The viscosity may depend on time

Some (many) may have both

Non-Newtonian or rheological fluids –

viscosity η is a function of the flow velocity

Examples of non-Newtonian fluids

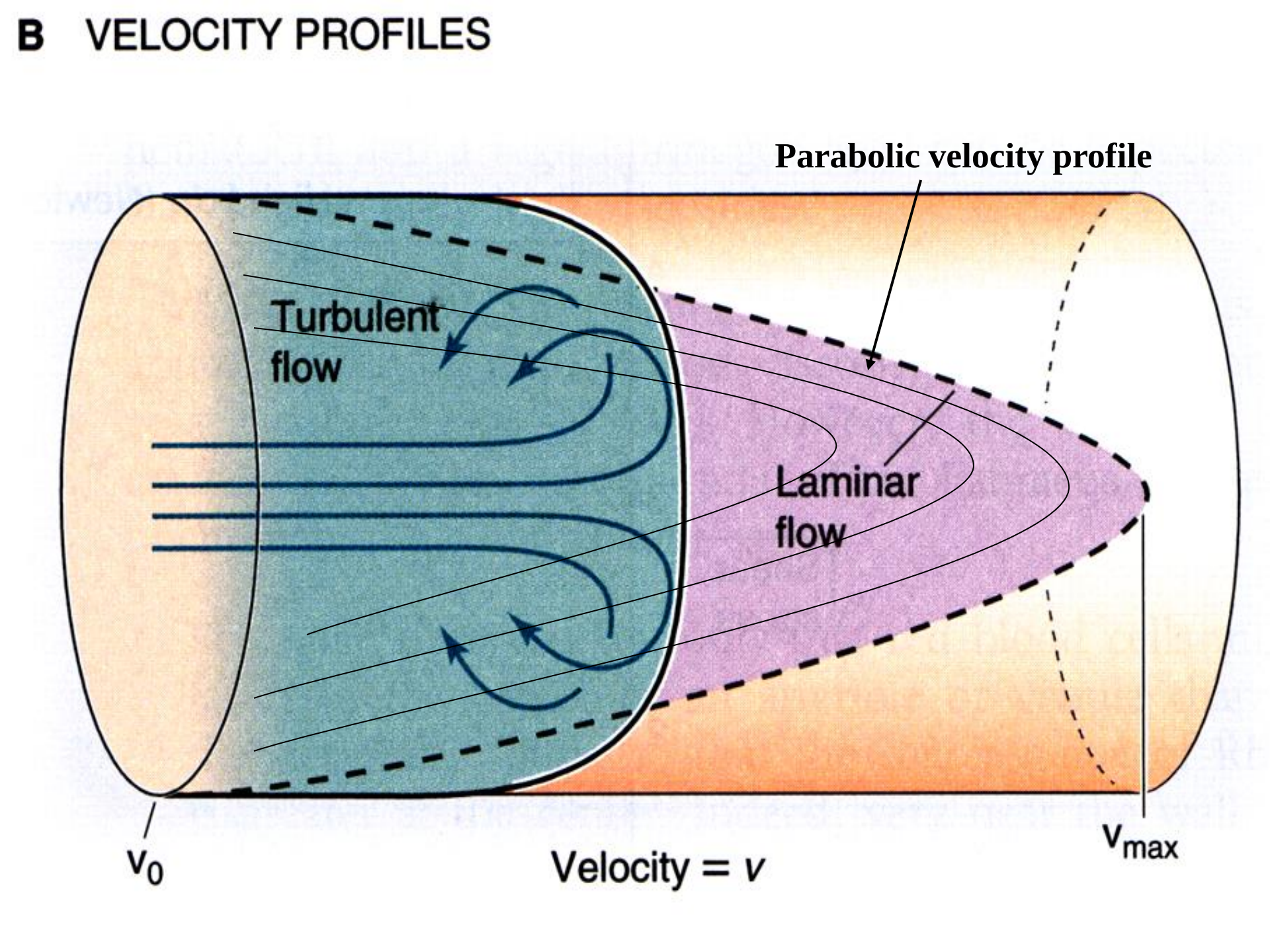
* Blood - it contains corpuscles and other suspended particles. The corpuscles can deform and become preferentially oriented so that the viscosity decreases to maintain the flow rate.
* Corn flour and water mixture.
* Certain soils (more clay content) are non-Newtonian when moist to wet.

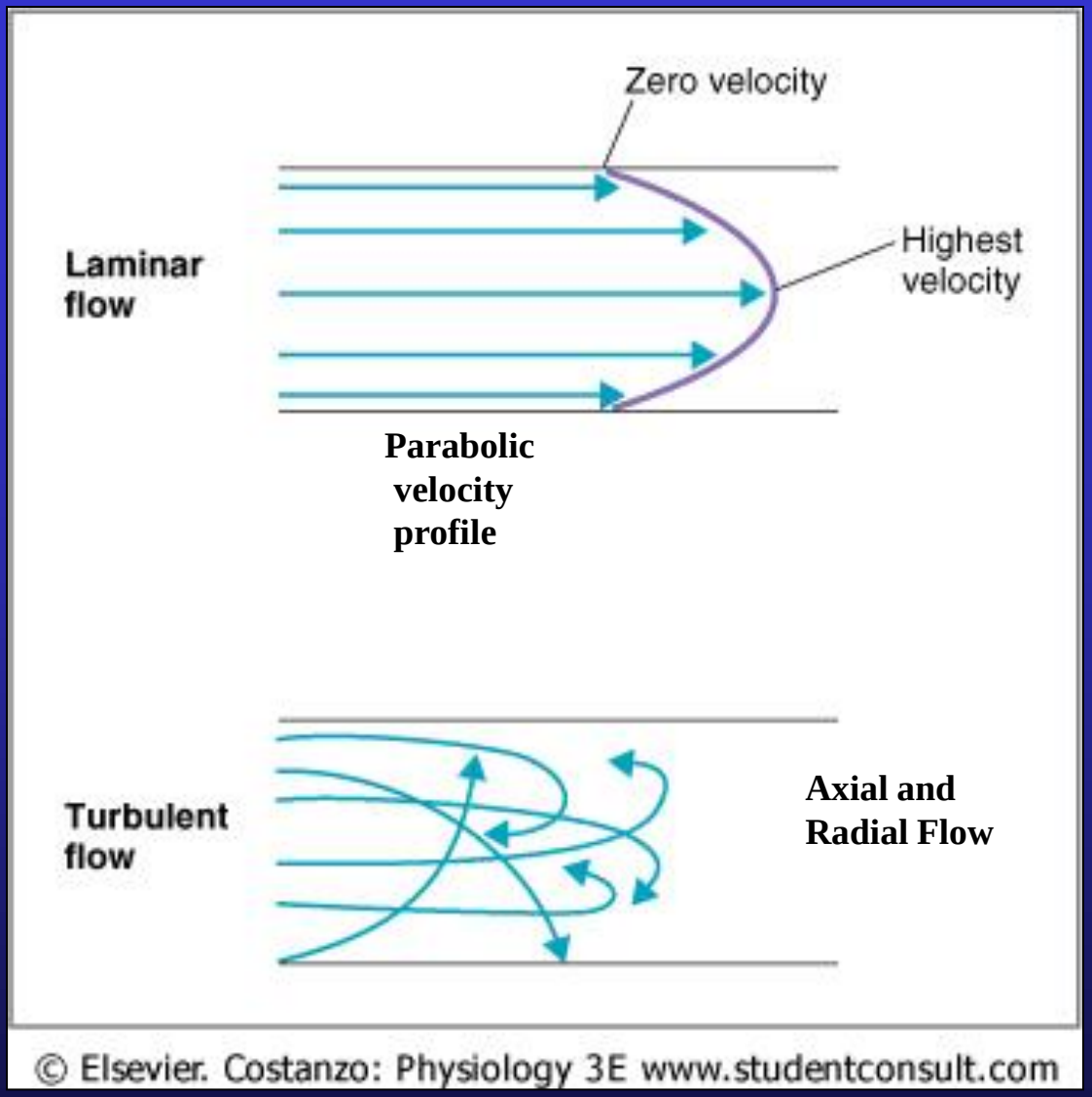
Laminar Flow-

- all points in fluid move parallel to walls of tube
- Each layer of blood stays at same distance from wall
- Blood cells forces to center of vessel

Turbulent Flow-

- At bifurcations of blood vessels
- Pressure drop greater than with laminar (square)
- Makes heart work harder
- Blood clots and thrombi much more likely to develop


B VELOCITY PROFILES
Parabolic velocity profile
Turbulent flow
Laminar flow
v_0
v_{max}
Velocity = v



Laminar Flow

Turbulent Flow

Comparison of laminar flow to turbulent blood flow..

http://ww nl

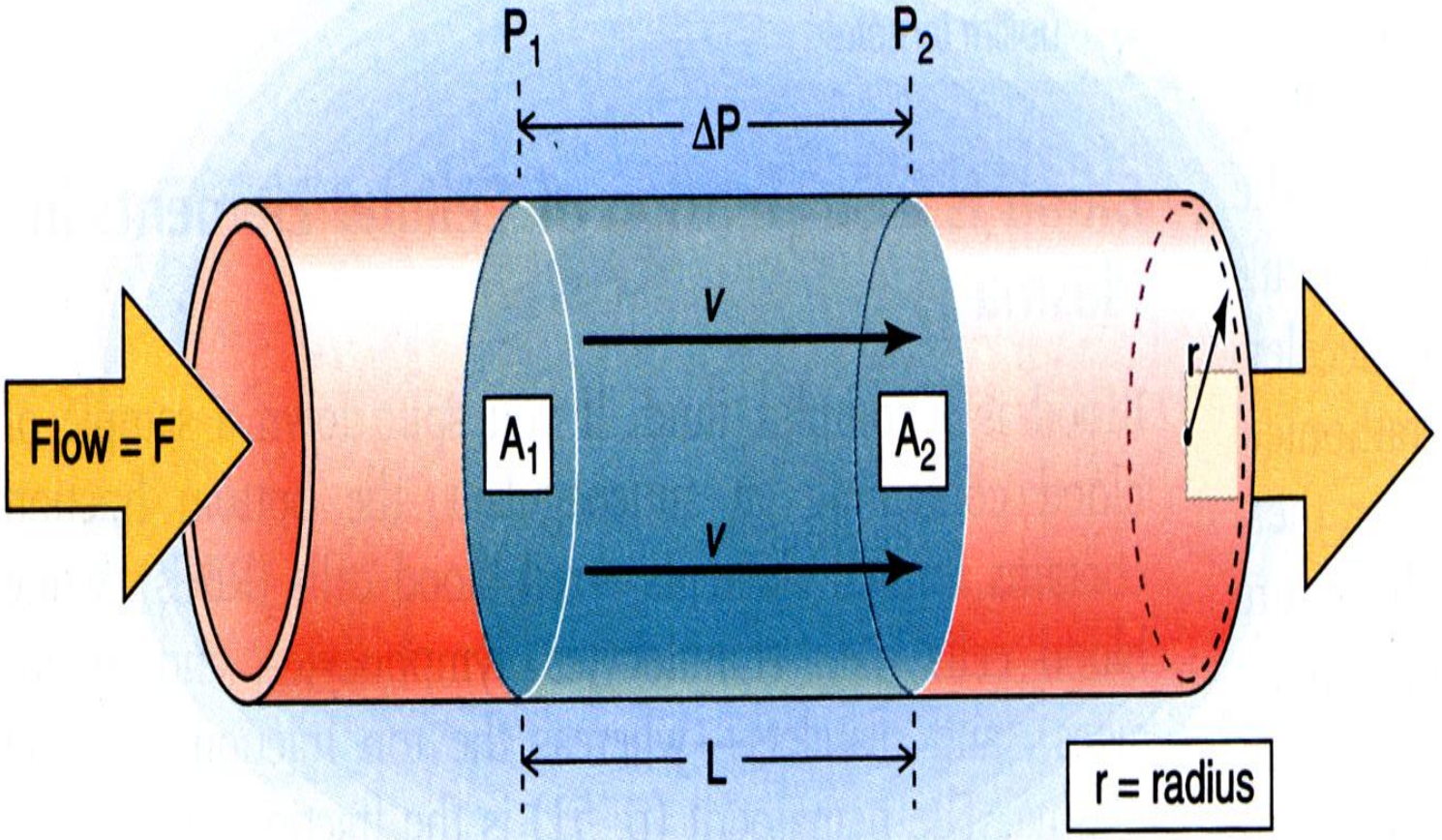
Laminar and Turbulent Flow Summary

- Laminar Flow

Layers of water flow over one another at different speeds with virtuall y no mixing between layers. The flow velocity profile for laminar flow in circular pipes is parabolic in shape, with a maximum flow in the center of the pipe and a minimum flow at the pipe walls. The average flow velocity is approximately one half of the maximum velocity.

- Turbulent Flow

The flow is characterized by the irregular movement of particles of the fluid. The flow velocity profile for turbulent flow is fairly flat across the center section of a pipe and drops rapidly extremely close to the walls. The average flow velocity is approximately equal to the velocity at the center of the pipe.



$$Q = \frac{\Delta P \ r^4 \ \pi}{\eta L \ 8}$$

Poiseuille's Law

Poiseuille's Law

$$Q = \frac{\Delta P \, \pi \, r^4}{\acute{\eta} \, L \, 8}$$

$$R = \frac{8 \, \acute{\eta} \, L}{\pi \, r^4}$$

$$Q = \Delta P / R$$

$$R = \Delta P / Q$$

Where:
R = Resistance
$\acute{\eta}$ = Viscosity of Blood
L = length of blood vessel
R^4 = radius of blood vessel raised to the 4^{th} power

APPLICATIONS

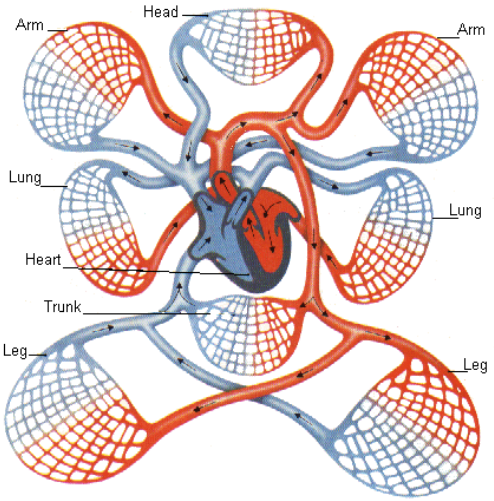
Irrigation pipes

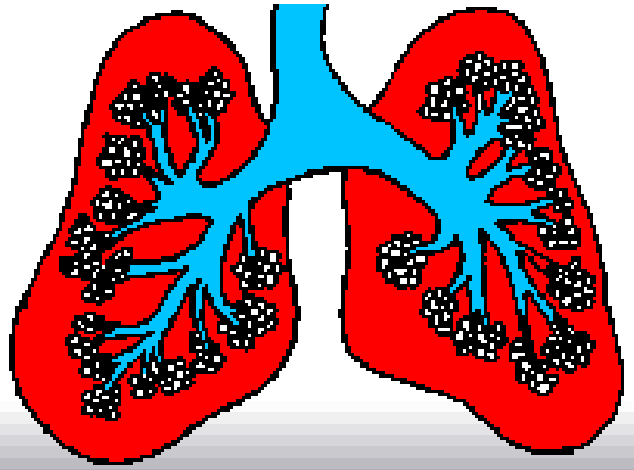
Pipes from Warragamba Dam

Respiratory system *Circulatory system*

Air conditioning, ducting, piping

Soils

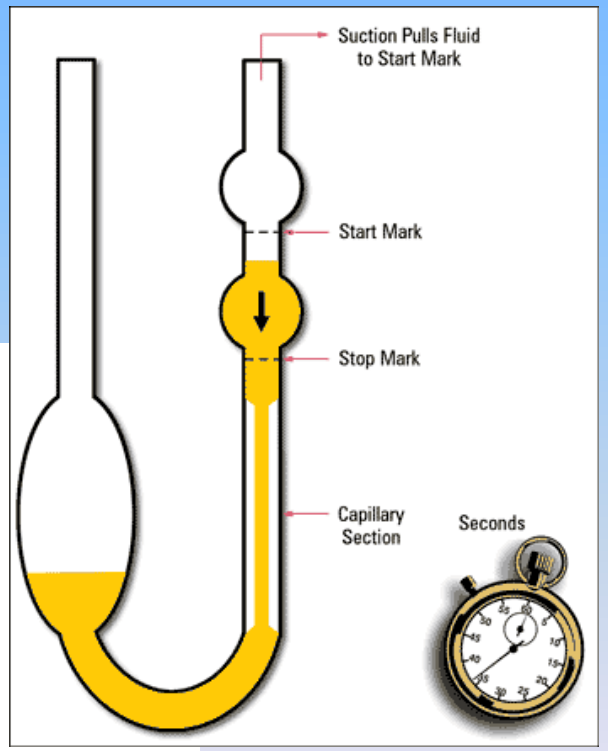




Viscosity Measurements

Capillary Viscometers

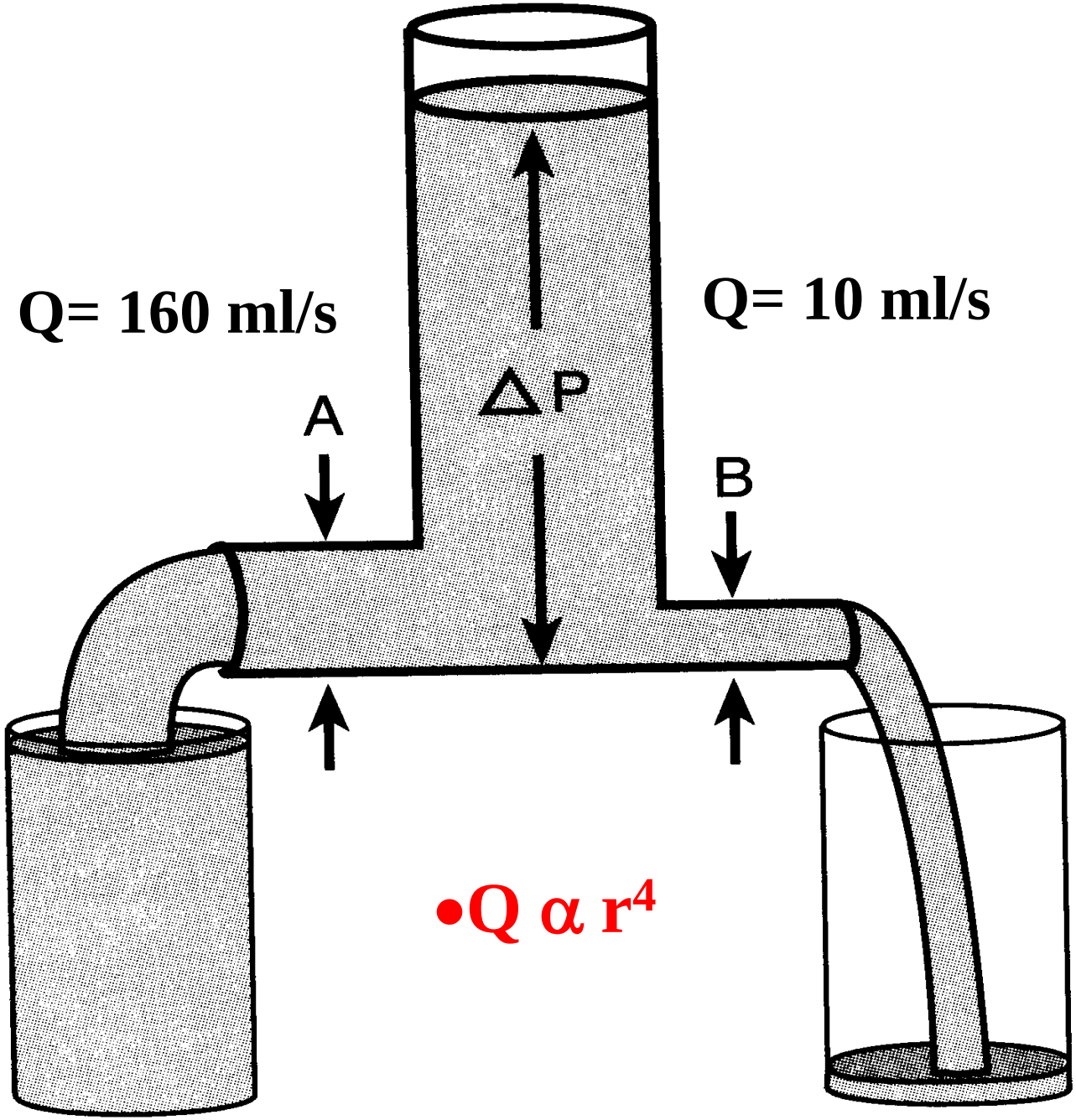
- It gives the '**kinematic viscosity**' of the fluid. It is based on Poiseuille's law for steady viscous flow in a pipe.



$$\upsilon = \pi r^4 g l t \,/\, 8LV = k(t_2 - t_1)$$

where:

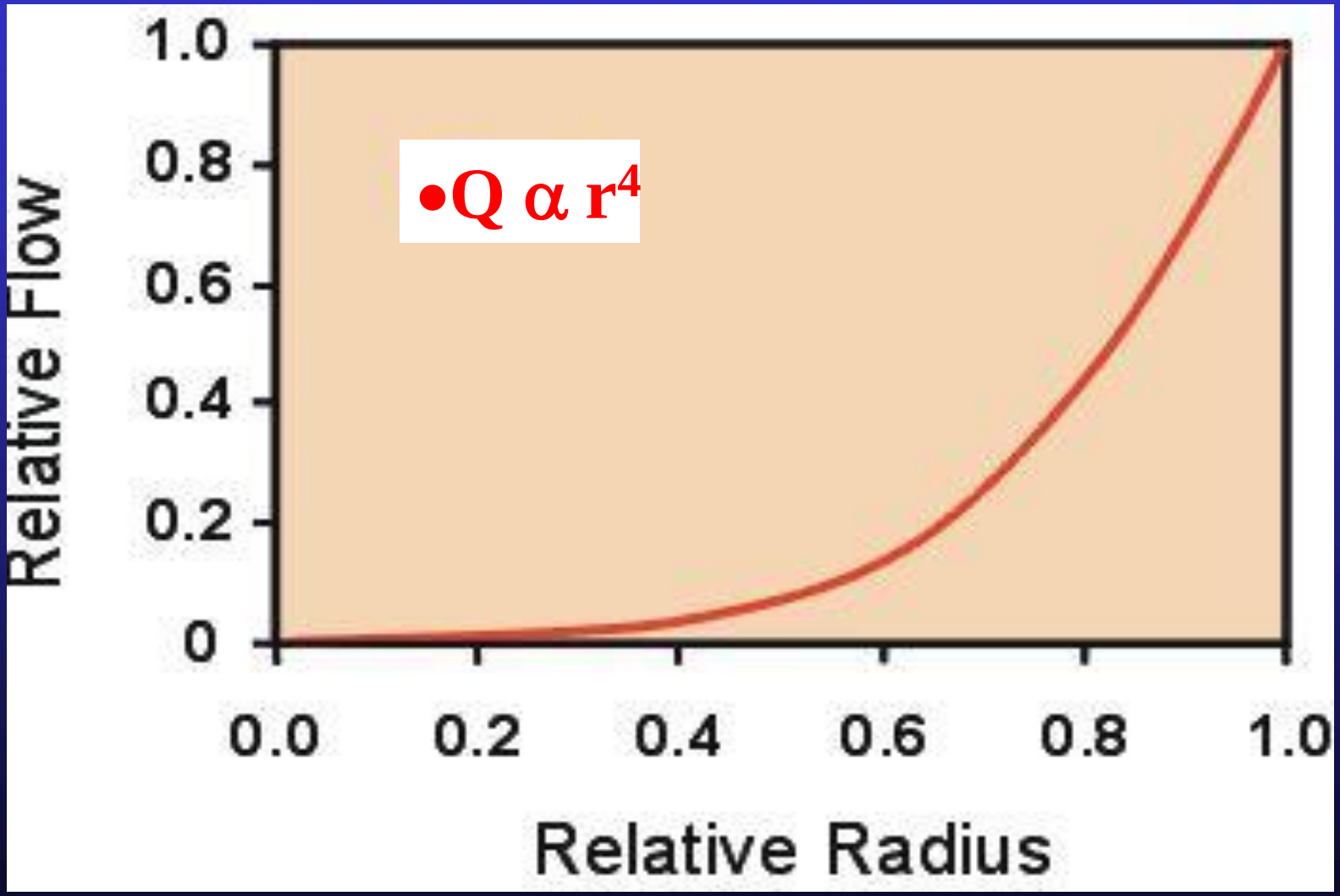
υ	is the kinematic viscosity [m^2/s];
r	is the capillary radius [m];
l	is the mean hydrostatic head [m];
g	is the earth acceleration [m/s^2];
L	is the capillary length [m];
V	is the flow volume of the fluid [m^3];
t	is the flow time through the capillary, $\mathbf{t = (t_2 - t_1)}$, [s];
k	is the capillary constant which has to be determined experimentally by applying a reference fluid with known viscosity, e.g. by applying freshly distilled water. The capillary constant is usually given by the manufacturer of the viscometer.



Flow is dependent on 4th power of the radius (r^4)

- **$Q \alpha r^4$**

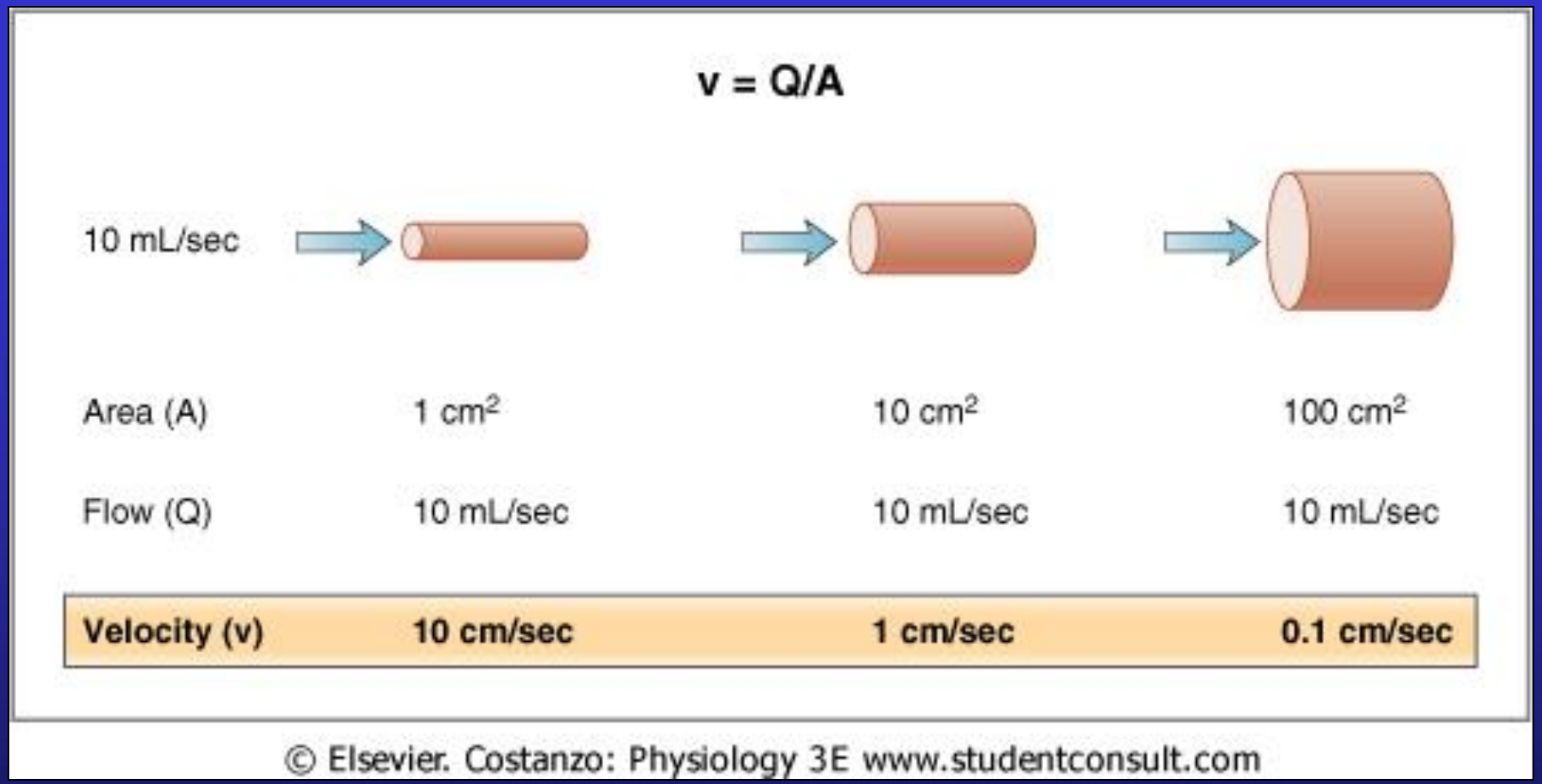
Effect of Radius on Flow



Poiseuille's Law - Assumptions

- Flow is steady (constant)
  - The pump (heart) is pulsatile
  - Arterial vessels dampen changes, but not steady
- Flow is laminar
  - Generally true except at bifurcations
- Fluid is Newtonian
  - Newtonian fluid is homogeneous, fixed viscosity
  - Is suspension, non-homogeneous
  - Viscosity increases with increasing hematocrit

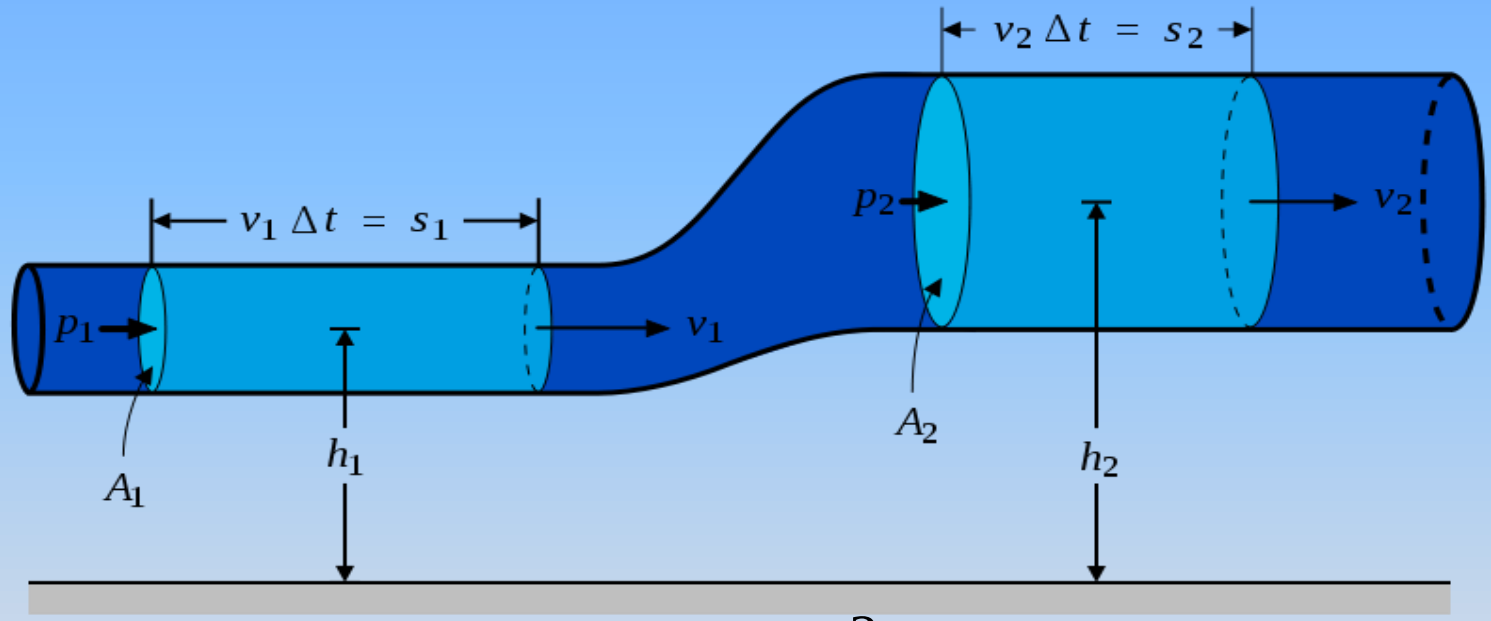
Vessels	Aorta	Artery	Arteriole	Capillary	Venule	Vein
radius, м	12×10^{-3}	$0,5\text{-}3\times10^{-3}$	$(10\text{-}100)\times10^{-6}$	3×10^{-6}	$(10\text{-}250)\times10^{-6}$	$(0,75\text{-}7,5)\times10^{-3}$
Pressure , P (кПа)	13,3	11,0	7,0	3,3	1,6	1,0
						



Effect of the diameter of the blood vessel on the velocity of blood flow

Bernulle's Law

For *steady flow*, the speed, pressure, and elevation of an *incompressible and nonviscous* fluid are related by an equation discovered by Daniel Bernoulli (1700–1782).



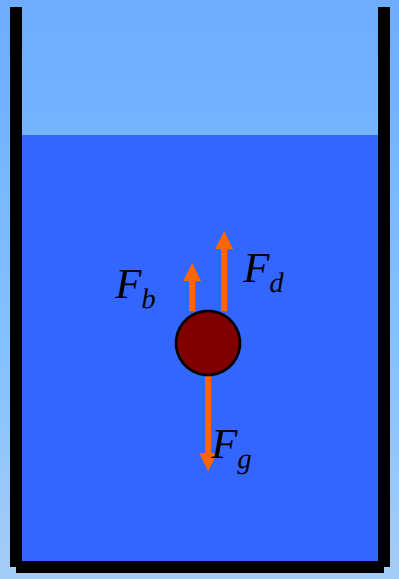
$$P + \rho g h + \frac{\rho v^2}{2} = const$$

STOKE'S LAW:

When a spherical object, moves through a viscous liquid there is a viscous drag force upon it:

$$F_{drag} = 6\pi r\eta v$$

where r = radius of sphere, η = viscosity and v = velocity of sphere.



Reynold's number

- A dimensionless number in fluid mechanics
- Dynamic Pressure : Shearing Stress
- Thus, it quantifies the relative importance of these two types of forces for given flow conditions.

- Arises when performing analysis of fluid dynamics
- Can be used to determine dynamic similitude in such cases. Concept used in the testing of models, e.g. testing miniature airplanes/submarines

Dynamic Pressure + Shearing Stress

- Dynamic Pressure
  - The pressure of a fluid which results from its motion
  - Formula: $q = \frac{1}{2}pv^2$

Fluid Density

Fluid Velocity

- Shearing Stress
  - Measure of the force of friction from a fluid acting on a body in the path of that fluid
  - Formula: $\tau = \gamma DSw$

Weight Density of Water

Average water depth

Water Surface Slope

Reynold's number

Flow in a pipe or liquid

- p is the density of the fluid
- V is the mean fluid velocity
- D is the diameter
- Q is the volumetric flow rate

$$\mathrm{Re} = \frac{\rho \mathrm{VD}}{\mu} = \frac{\mathrm{VD}}{\nu} = \frac{\mathrm{QD}}{\nu A}$$

Dynamic Pressure

- μ is the dynamic viscosity of the fluid
- v is the kinematic velocity of the fluid
- A is the pipe cross-sectional area.

Shearing Stress

Reynold's number

- The Reynold's number can be used to determine if a flow is laminar, transient or turbulent

- Laminar when $Re < 2300$
- Turbulent when $Re > 4000$
- Transient when $2300 < Re < 4000$


THANK YOU FOR
YOUR
ATTENTION!!!