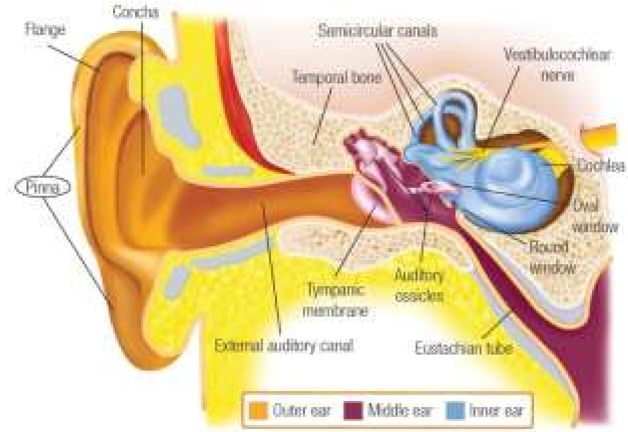
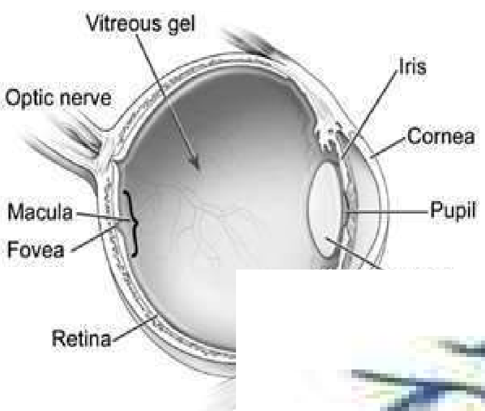
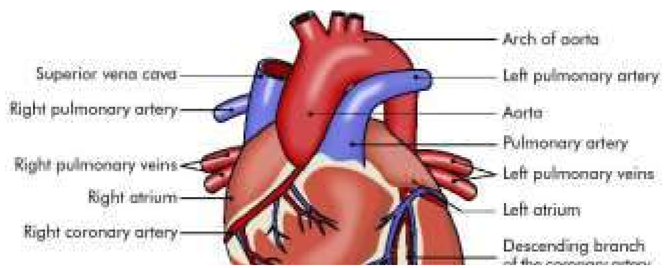
Biophysics
Second stage

The Lecturer\ Fala Hatem







Lecture 1 of biophysics

Fundamentals of Biomechanics

Biomechanics

Biomechanics: Applications of mechanics to the human body and s implements, and studies forces on (and by) the human body and s results of those forces

Kinematics: study of motion (change in position) of a body or object

Kinetics: forces involved in the movement of an object or body

- **Linear motion**: in a straight line
- **Curvilinear motion**: in a curve
- **Angular (rotational) motion**: around an axis
- **General motion**: linear and angular motion together
- **Linear kinetics**: force, gravity, mass and weight
- **Angular kinetics**: torque (moments), levers

Biomechanics

Motion - Linear

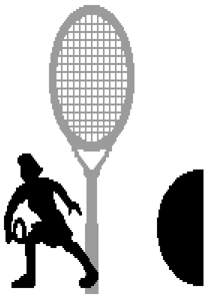
When a body moves in a straight line with all its parts moving the same DISTANCE, DIRECTION, and SPEED

SPORTING EXAMPLE = THE BOB SLEIGH

(TOBOGGAN)

Everything is moving in the same direction and at the same speed

Biomechanics



Motion lar

When a body or part of a body moves in a circle or part of a circle about a point (the axis of rotation).

Circular motion about a point. i.e. The elbow being fixed when the forearm moves in a half circle in a tennis serve.

Biomechanics

Motion -General

General motion is a combination of Angular and Linear r

General = Angular + Linear

SPORTING EXAMPLE =

Javelin

Wheel chair athletics

Swimming

Running

Biomechanics

Scalars and Vectors

A Scalar quantity has only magnitude
A Vector quanitity has both magnitude and direction

Scalar Quantities

Length
Area
Volume
Speed
Mass
Density
Pressure
Temperature
Work
Power
Energy

Vector Quantiites

Displacement
Direction
Velocity
Acceleration
Momentum
Force
Lift
Drag
Thrust
Weight

Biomechanics

Speed vs Velocity

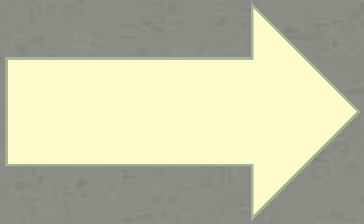
Speed is simply how fast you are travelling

Yohan Blake is travelling at a speed of 10 m/s

Biomechanics

Speed vs Velocity

Velocity is speed in a given direction



Yohan Blake is travelling at a speed of 10 m/s East

Biomechanics

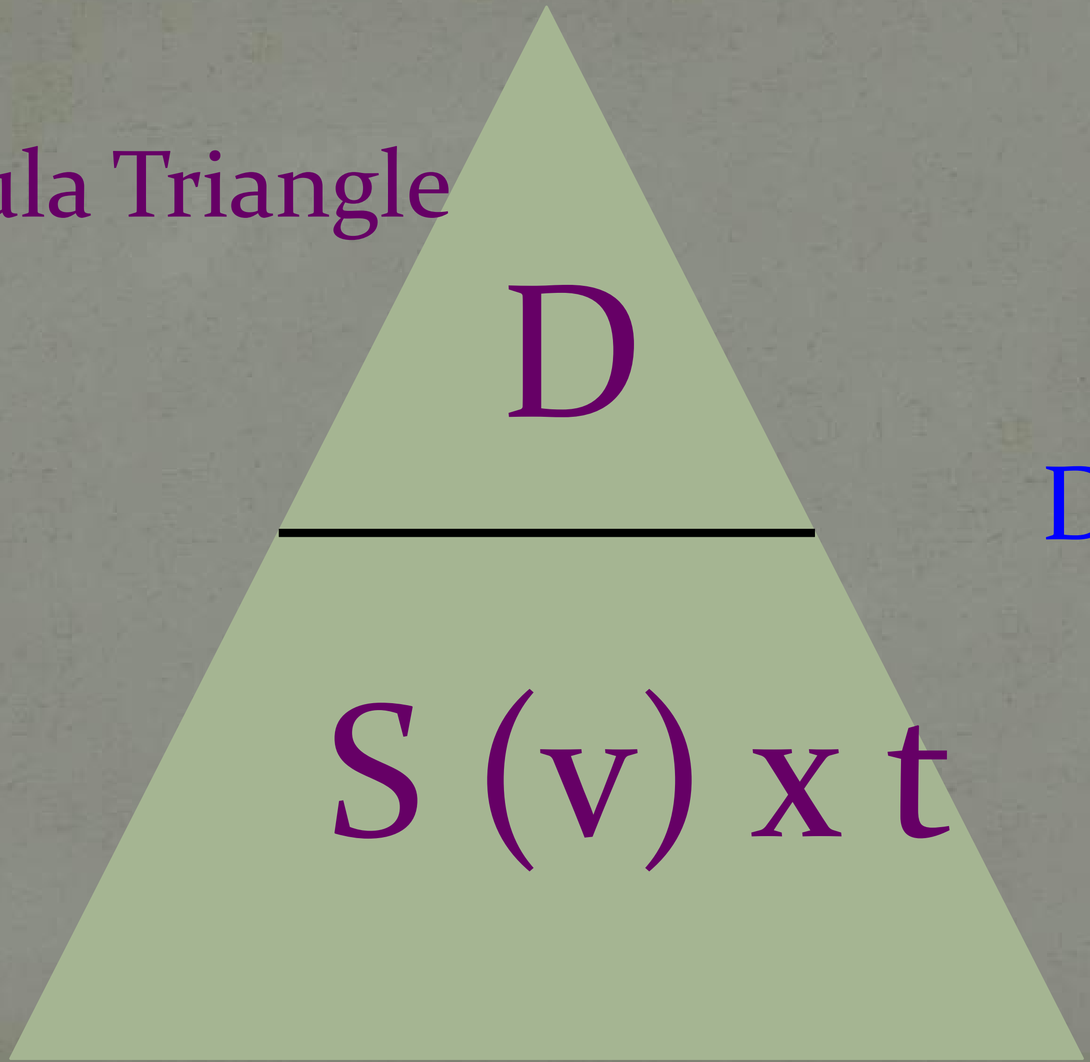
Speed (Velocity)

Speed = (Velocity)	Distance travelled / Time taken	Meters / Second

$$\text{Speed (Velocity)} = \frac{\text{Distance travelled}}{\text{Time taken}} \quad \frac{\text{Meters}}{\text{Second}}$$

Biomechanics

Formula Triangle



D = S x t

Biomechanics

Group Activity

Usian Bolt ran 100 m in 9.58 seconds, what was his average speed?

10.43 m/s

Biomechanics

Individual activity

- Try the practice questions in your booklet

Lionel Messi kicks a ball 6.5 meters. How much time is needed for the ball to travel this distance if its velocity is 22 meters per second, south?

t= d/s = 6.5m / 22ms-1 = 0.3s

Biomechanics

Individual activity

Andy Murray serves a tennis ball to Rafael Nadal. It travels 9.5 meters south in 2.1 seconds.

a. What is the velocity of the tennis ball?

v= d/t = 9.5m/2.1s = 4.5 ms-1 South

Biomechanics

Individual activity

b. If the tennis ball travels at constant speed, what is its velocity
when Nadal returns Murray's serve?

4.5 ms^{-1} north

Biomechanics

Acceleration

Acceleration = $\frac{\text{Change in velocity}}{\text{Time Taken}}$

This is ~ 186 m/h

Example:
A Formula 1 McLaren can do from 0 – 300,000m in 8.6 seconds. What is the acceleration?

Velocity (v) = $\frac{300000 \text{ m/h} - 0 \text{ m/h}}{8.6 \text{ s}} = \Delta v = \frac{300000 \text{ m/h}}{8.6 \text{ s}}$

Biomechanics

Acceleration

Acceleration = $\frac{\text{Change in velocity}}{\text{Time Taken}}$

Example:
A Formula 1 McLaren can do from 0 – 300000 m/h in 8.6 seconds. What is the acceleration?

This is ~ 186 m/h

$$\text{Acceleration (a)} = \frac{\Delta v}{t} = \frac{300000 \text{ m/h}}{8.6 \text{ s}}$$

300000 m/h is 83.3 m/s

$$a = \frac{83.3 \text{ m/s}}{8.6 \text{ s}} = 9.7 \text{ m/s}^2$$

Biomechanics

1. A skater goes from a standstill to a speed of 6.7 m/s in 12 seconds. What is the acceleration of the skater?

$$\frac{6.7\ \text{m/s}}{12\ \text{s}} = 0.56\ \text{m/s}^2$$

2. As a shuttle bus comes to a normal stop, it slows from 9.00m/s to 0.00m/s in 5.00s. Find the average acceleration of the bus.

$$-\frac{9\ \text{m/s}}{5\ \text{s}} = -1.8\ \text{m/s}^2$$

Biomechanics

3. During a race, a sprinter increases from 5.0 m/s to 7.5 m/s over a period of 1.25s. What is the sprinter's average acceleration during this period?

$$\frac{2.5 \text{ m/s}}{1.25 \text{ s}} = 2.0 \text{ m/s}^2$$

4. A wheel chair athlete starts from rest and accelerates at a constant rate of 1.500 m/s². What is the speed of the athlete after it they have traveled for 4.75 seconds?

$$4.74 \text{ s} \times 1.5 \text{ m/s}^2 = 7.125 \text{ m/s}$$

Biomechanics

5. During a 1600 m race, a runner starts their kick to the finish at the 1400 m mark to the finish at 1600 m, it takes them 28 seconds to cover that distance. What is their average speed?

$$\frac{200\ m}{28\ s} = 7.14\ m/s$$

Biomechanics

7. A cyclist accelerates at $0.89 m/s^2$ during a 5.0s interval. What is the change in the speed of the bicyclist and the bicycle?

$0.89 m/s^2 \times 5.0\ s = 4.45\ m/s$

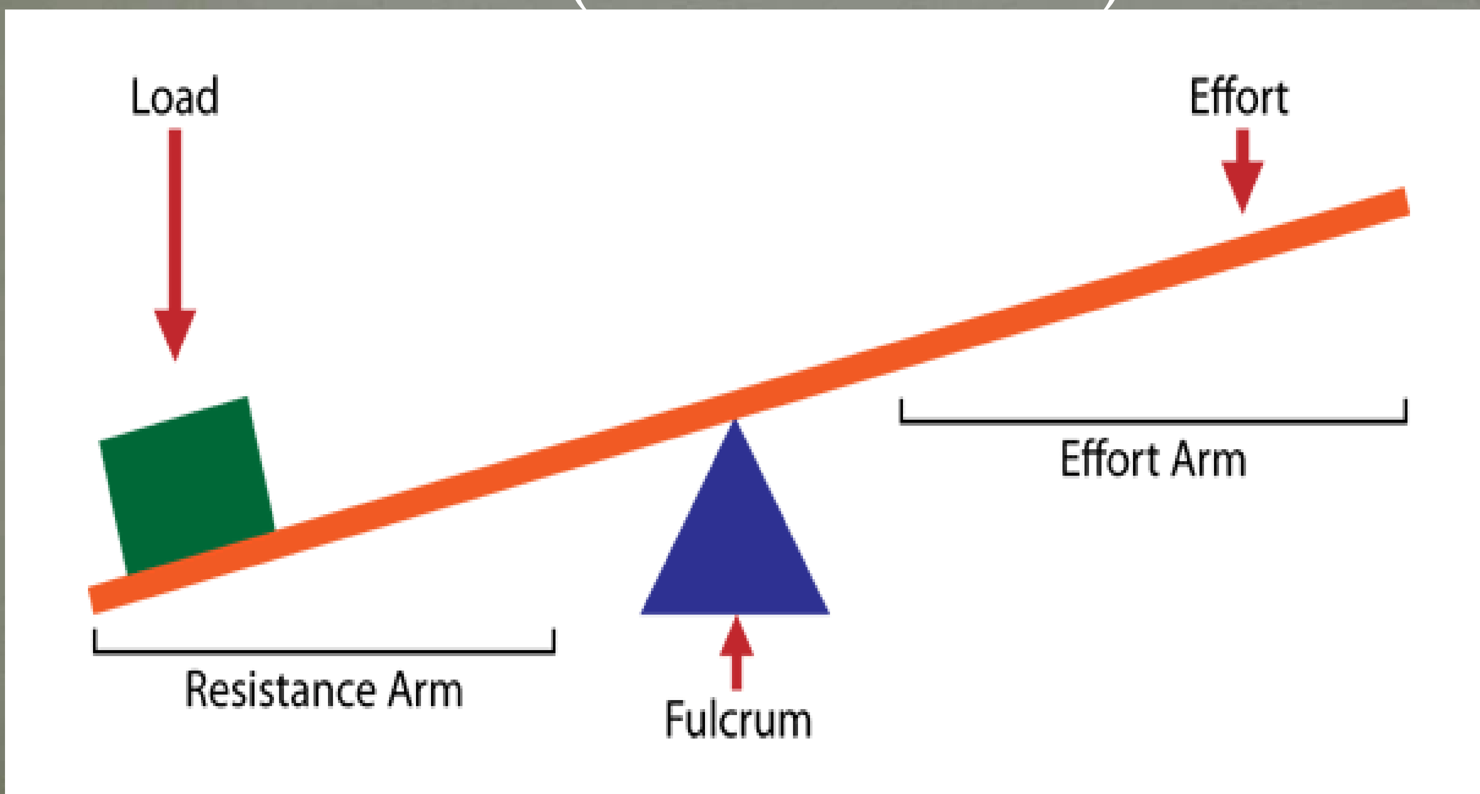
8. If a rocket undergoes a constant total acceleration of $6.25 m/s^2$, so that its speed increases from rest to about 750m/s, how long will it take for the rocket to reach 750m/s?

$$\frac{750\ m/s}{6.25 m/s^2} = 120\ s$$

Levers

What is a lever?

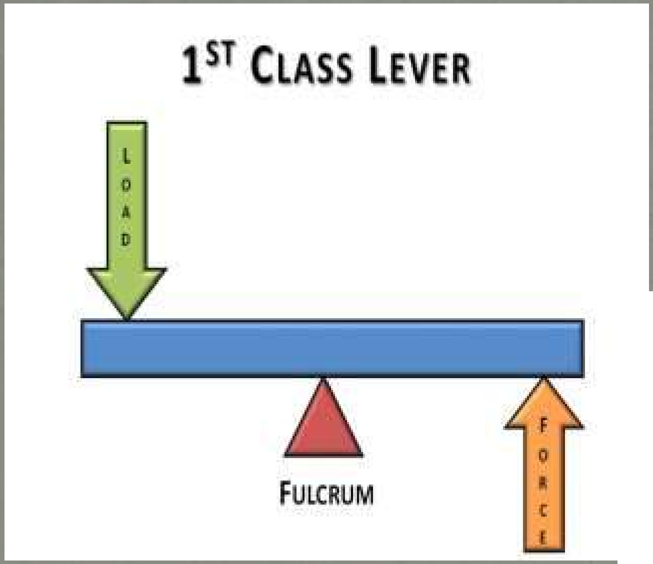
Rigid structures hinged at one point (fulcrum) to which forces are applied to two other points (effort and load)

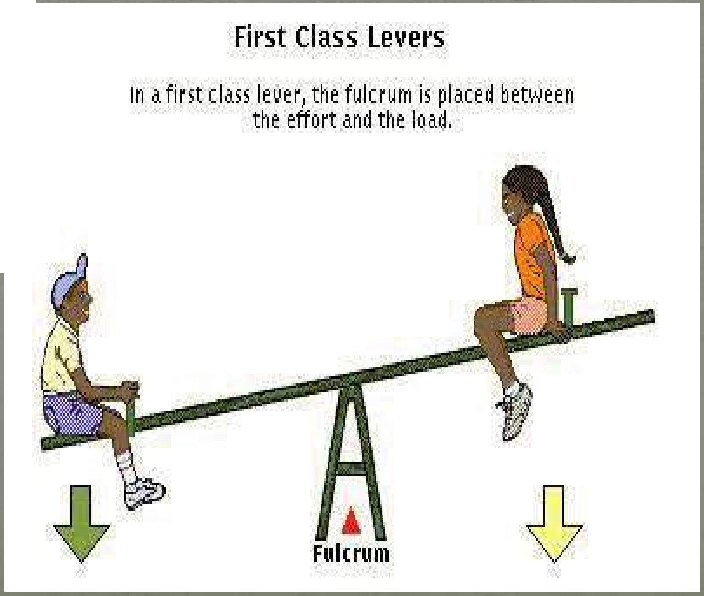


Levers

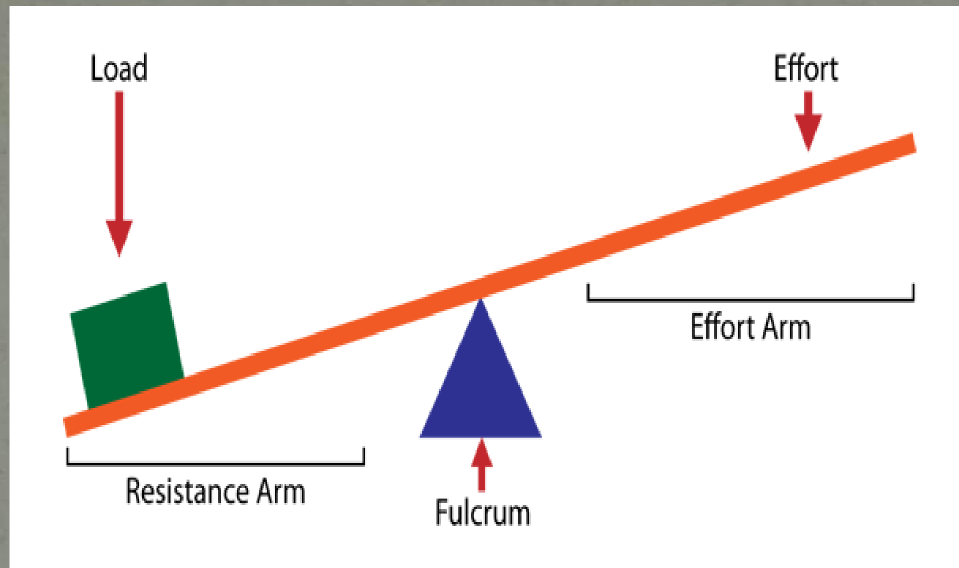
1. First Class Lever:

The fulcrum lies between the effort and load.





Levers

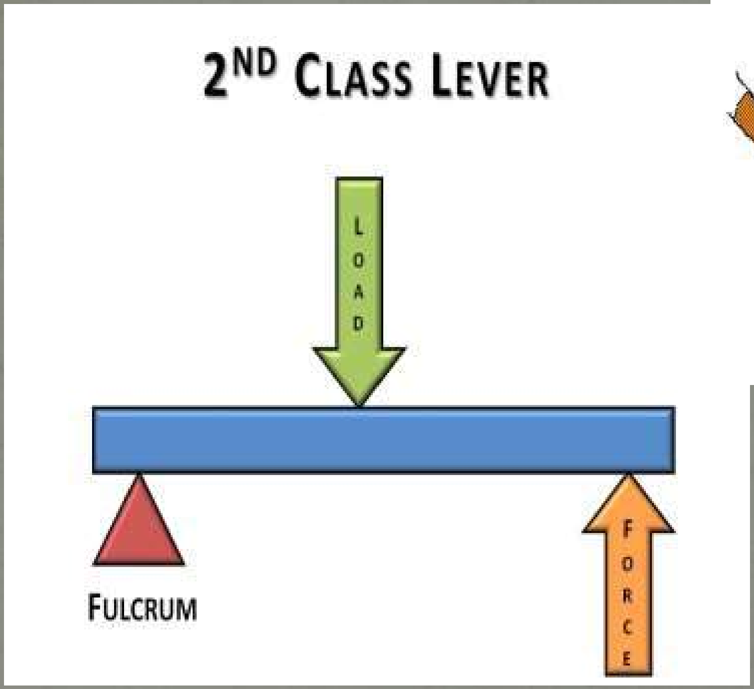


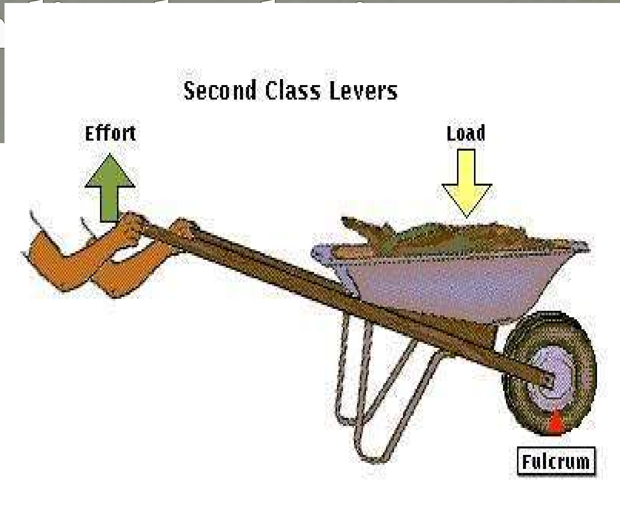
Resistance arm- distance between load & fulcrum

Effort arm- distance between effort & fulcrum

Levers

2. Second Class Lever: the fulcrum lies at one end with the effort at the other and the load in the middle. Ex. Stan

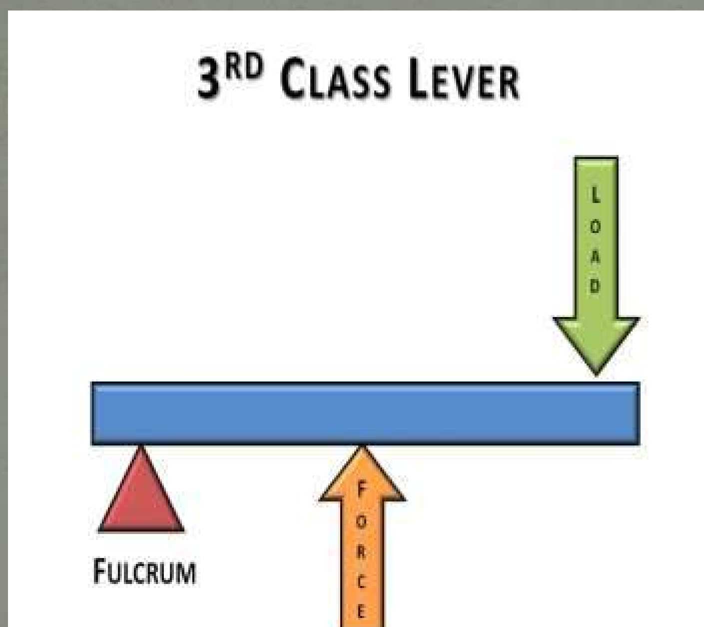




mechanical advantage is greater than 1, which means larger loads can be moved with

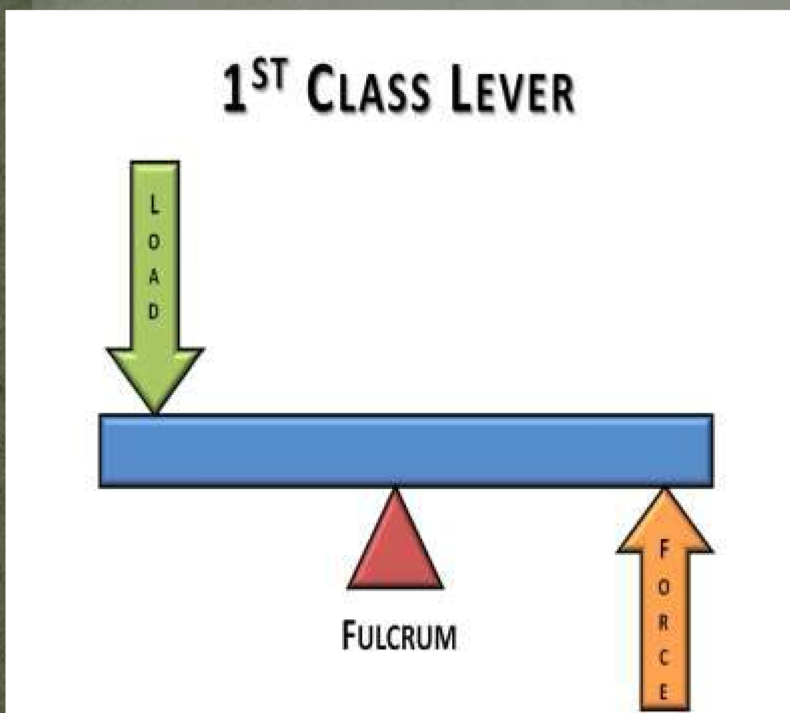
Levers

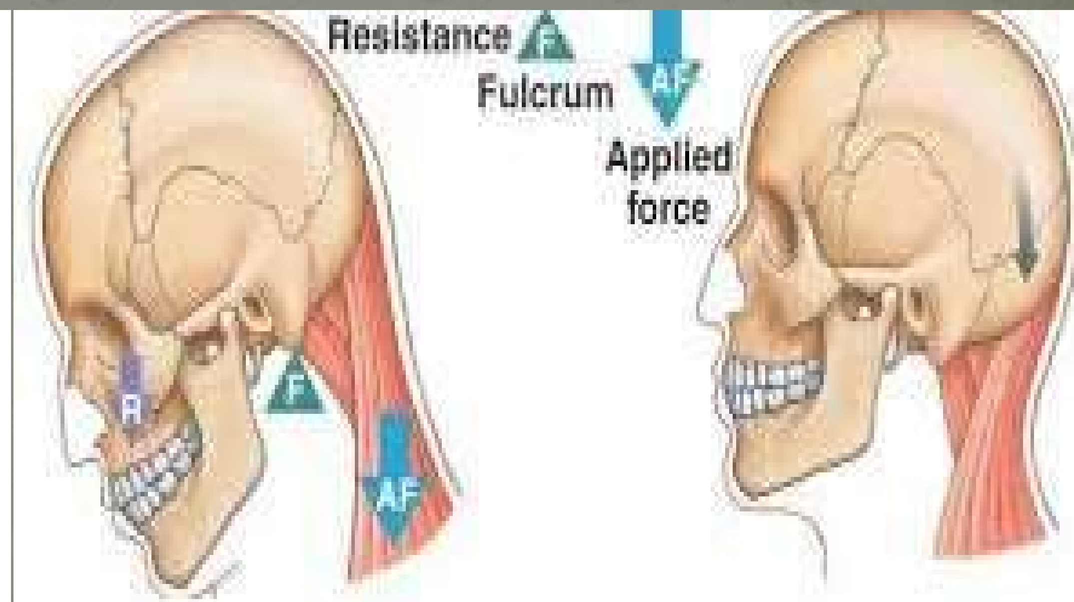
3. <u>Third Class Levers</u>: the effort lies between the load and



Mechanical advantage is less than 1, which means more effort to move smaller loads.

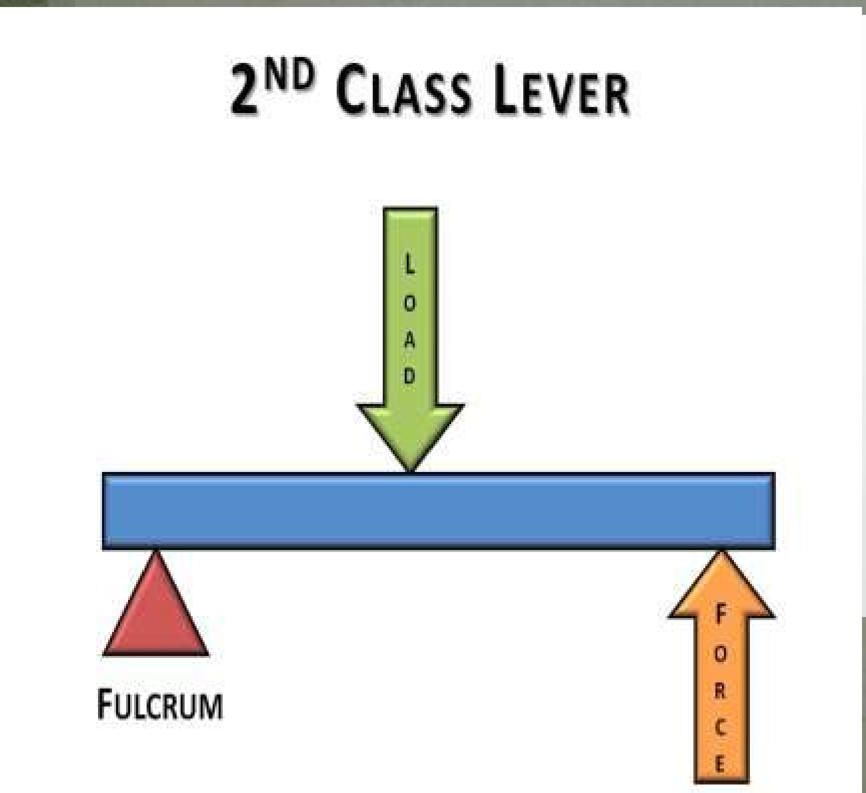
Human body and Levers





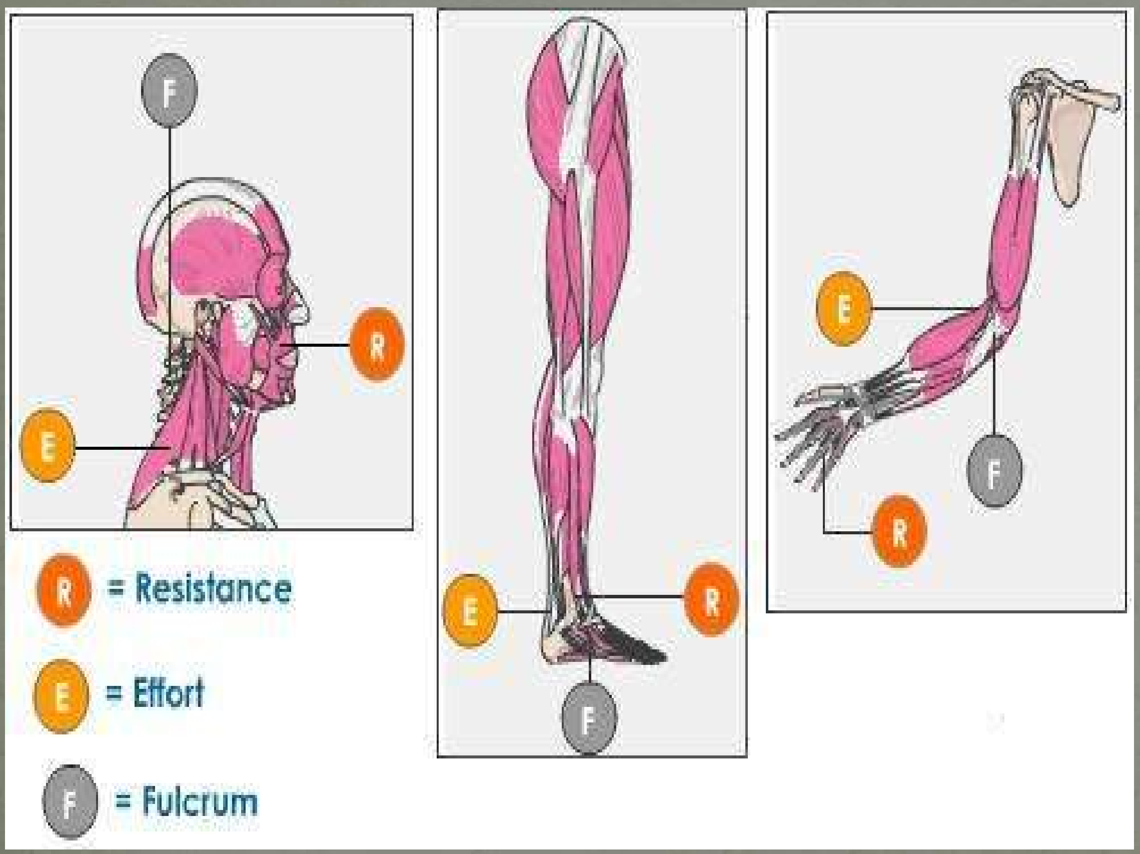
Human body and Levers

What type of lever is at the toes joints when you go up on



Levers

Types of Levers



https://www.youtube.com/watch?v=ny8k7LUUIEk

Lecture 2 of biophysics

GASES

- Gases are one of the most pervasive aspects of our environment on the Earth. We continually exist with constant exposure to gases of all forms.
- The steam formed in the air during a hot shower is a gas.
- The Helium used to fill a birthday balloon is a gas.
- The oxygen in the air is an essential gas for life.

Important Characteristics of Gases

1) Gases are highly compressible

An external force compresses the gas sample and decreases its volume, removing the external force allows the gas volume to increase.

2) Gases are thermally expandable

When a gas sample is heated, its volume increases, and when it is cooled its volume decreases.

3) Gases have high viscosity

Gases flow much easier than liquids or solids.

4) Most Gases have low densities

Gas densities are on the order of grams per liter whereas liquids and solids are grams per cubic cm, 1000 times greater.

5) Gases are infinitely miscible

Gases mix in any proportion such as in air, a mixture of many gases.

Kinetic Molecular Theory

- However, before understanding the mathematics of gases, a chemist must have an understanding of the conceptual description of gases. That is the purpose of the *Kinetic Molecular Theory*.

- The Kinetic Molecular Theory is a single set of descriptive characteristics of a substance known as the Ideal Gas.

The Nature of Gases

Three basic assumptions of the kinetic theory as it applies to gases:

1. Gas is composed of particles- usually molecules or atoms
   - Small, hard spheres
   - Insignificant volume; relatively far apart from each other
   - No attraction or repulsion between particles

The Nature of Gases

2. Particles in a gas move rapidly in constant *random* motion
   - Move in straight paths, changing direction only when colliding with one another or other objects
   - Average speed of O_2 in air at 20 ^{o}C is an amazing 1660 km/h.

The Nature of Gases

3. Collisions are perfectly elastic- meaning kinetic energy is transferred without loss from one particle to another- the total kinetic energy remains constant

IDEAL GAS MODEL

- The gas consists of objects with a defined mass and zero volume.
- The gas particles travel randomly in straight-line motion where their movement can be described by the fundamental laws of mechanics.

- All collisions involving gas particles are elastic; the kinetic energy of the system is conserved even though the kinetic energy among the particles is redistributed.

- The gas particles do not interact with each other or the with the walls of any container.
- The gas phase system will have an average kinetic energy that is proportional to temperature; the kinetic energy will be distributed among the particles according to a Boltzmann type of distribution.

Boltzman Distribution. The behaviour of the gas molecules under the action of gravity.

Ideal Gas Model

Kinetic Molecular Theory (KMT) for an ideal gas states that all gas particles:

- are in random, constant, straight-line motion.
- are separated by great distances relative to their size; the volume of the gas particles is considered negligible.
- have no attractive forces between them.
- have collisions that may result in the transfer of energy between gas particles, but the total energy of the system remains constant.

Deviations from ideal behaviour

- **A real gas is most like an ideal gas when the real gas is at low pressure and high temperature.**

- At high pressures gas particles are close therefore the volume of the gas particles is considered.
- At low temperatures gas particles have low kinetic energy therefore particles have some attractive force

Gas Law Variables

- In order to describe gases, mathematically, it is essential to be familiar with the variables that are used. There are four commonly accepted gas law variables

- Temperature
- Pressure
- Volume
- Moles

Temperature

- The temperature variable is always symbolized as T.
- It is critical to remember that all temperature values used for describing gases must be in terms of absolute kinetic energy content for the system.

- Consequently, T values must be converted to the Kelvin Scale. To do so when having temperatures given in the Celsius Scale remember the conversion factor
- Kelvin = Celsius + 273

Pressure

- The pressure variable is represented by the symbol P.
- The pressure variable refers to the pressure that the gas phase system produces on the walls of the container that it occupies.

- The phenomenon of pressure is really a force applied over a surface area. It can best be expressed by the equation

$$\text{Pressure} = \frac{\text{Force}}{\text{Surface Area}}$$

Volume

- The Volume variable is represented by the symbol V. It seems like this variable should either be very easy to work with or nonexistent.
- Remember, according to the Kinetic Molecular Theory, the volume of the gas particles is set at zero. Therefore, the volume term V seems like it should be zero.
- In this case, that is not true. The volume being referred to here is the volume of the container, not the volume of the gas particles.
- The actual variable used to describe a gas should be the amount of volume available for the particles to move around in. In other words

$$Volume_{(Available)} = Volume_{(Container)} - Volume_{(Particles)}$$

Moles

- The final gas law variable is the quantity of gas. This is always expressed in terms of moles. The symbol that represents the moles of gas is n.

Conclusions

There are four variables used mathematically for describing a gas phase system. While the units used for the variables may differ from problem to problem, the conceptual aspects of the variables remain unchanged.

1. T, or Temperature, is a measure of the average kinetic energy of the particles in the system and must be expressed in the Kelvin Scale.
2. P, or Pressure, is the measure of the amount of force per unit of surface area. If the gas is not in a container, then P represents the pressure it could exert if it were in a container.
3. V, or Volume, is a measure of the volume of the container that the gas could occupy. It represents the amount of space available for the gas particles to move around in.
4. n, or Moles, is the measure of the quantity of gas. This expresses the number of objects in the system and does not directly indicate their masses.

Gas Laws

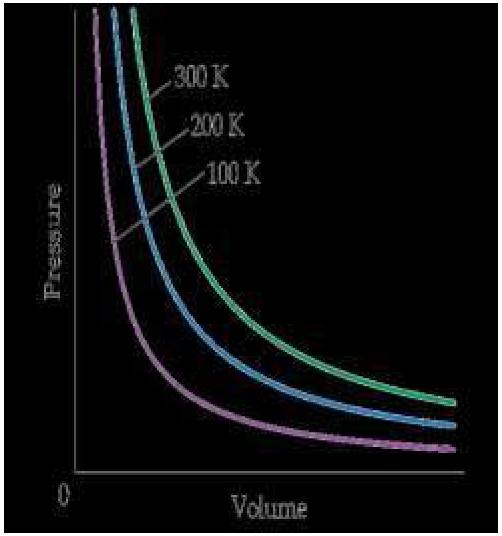
- (1) When temperature is held constant, the density of a gas is proportional to pressure, and volume is inversely proportional to pressure. Accordingly, an increase in pressure will cause an increase in density of the gas and a decrease in its volume. – **Boyles's Law**

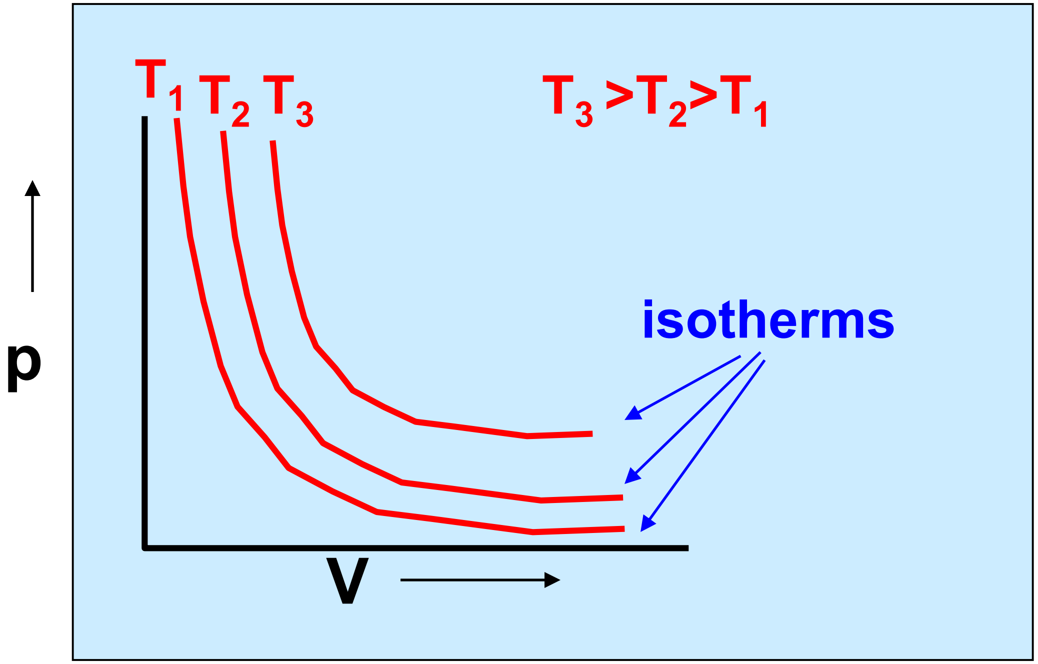
- (2) If volume is kept constant, the pressure of a unit mass of gas is proportional to temperature. If temperature increase so will pressure, assuming no change in the volume of the gas.

- (3) Holding pressure constant, causes the temperature of a gas to be proportional to volume, and inversely proportional to density. Thus, increasing temperature of a unit mass of gas causes its volume to expand and its density to decrease as long as there is no change in pressure. **- Charles's Law**

Boyle's Law

- Hyperbolic Relation Between Pressure and Volume



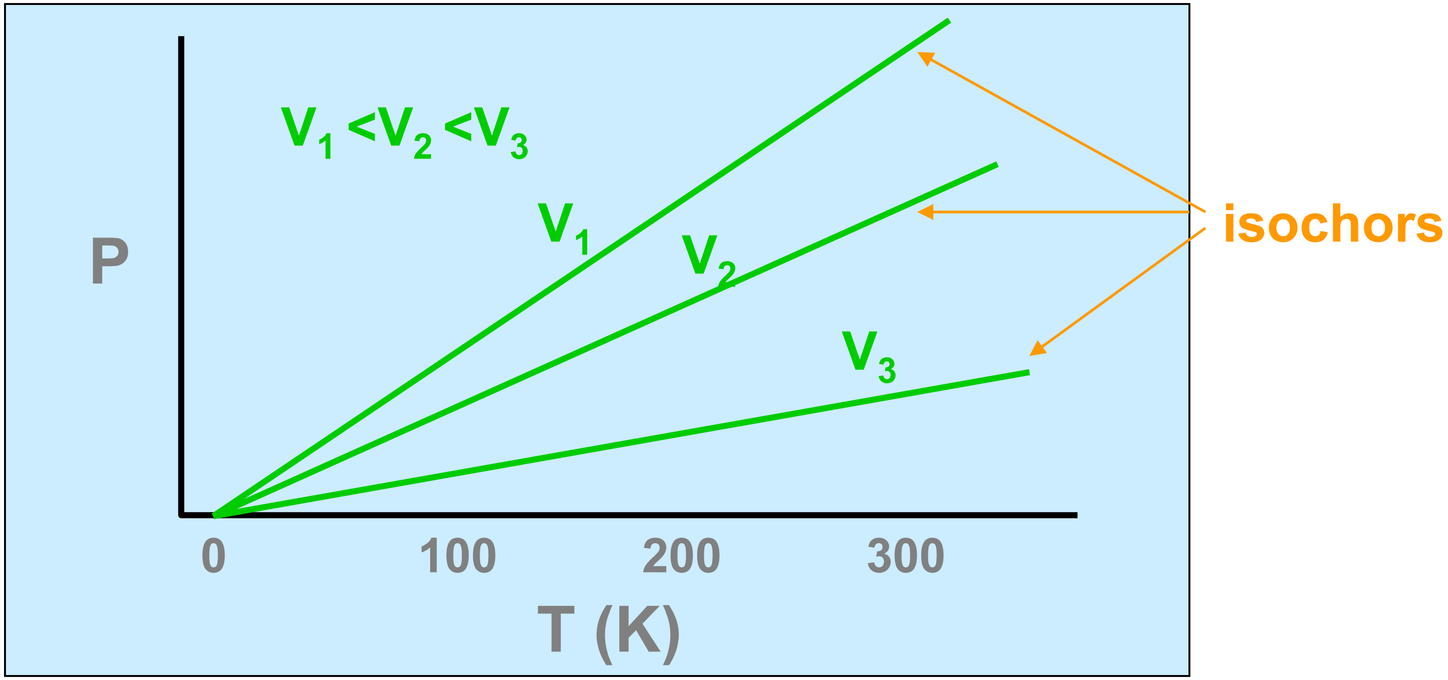


p – V Diagram

(courtesy F. Remer)

Charles' Law

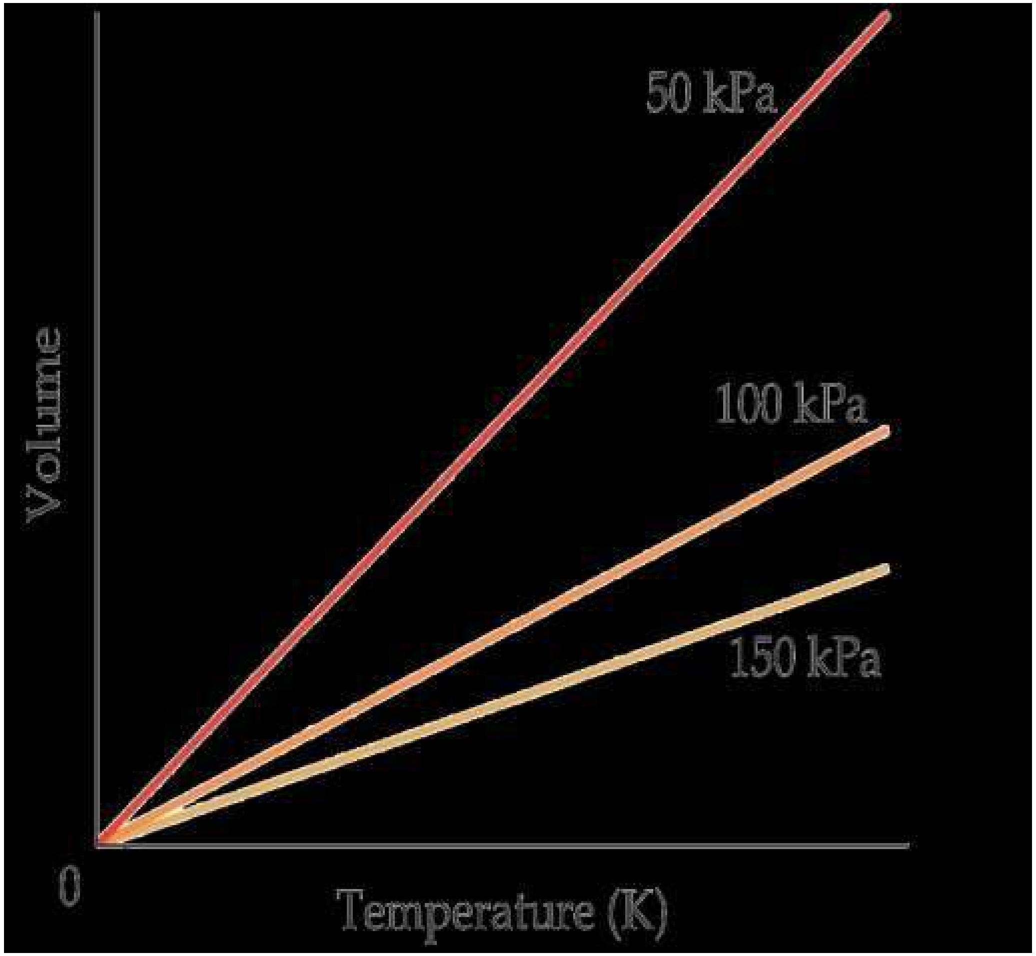
- Linear Relation Between Temperature and Pressure



P – T Diagram

(courtesy F. Remer)

Charles' Law



Real data must be obtained above liquefaction temperature. Experimental curves for different gasses, different masses, different pressures all extrapolate to a common zero.

Ideal Gas Law

The equality for the four variables involved in Boyle’s Law, Charles’ Law, Lussac’s Law and Avogadro’s law can be written

$$PV = nRT$$

R = ideal gas constant

Lecture 3 of biophysics

Thermodynamics

The heat

- The term heat refers is the energy that is transferred from one body or location due to a difference in temperature. This is similar to the idea of work, which is the energy that is transferred from one body to another due to forces that act between them. Heat is internal energy when it is transferred between bodies.

- ***Different kinds of scales: -*** There are three famous degrees to measure the temperature are :-
- ***1- Celsius (centigrade C˚)***
- ***2- (Fahrenhit F˚)***
- ***3- Absolute (Kelvin) K˚***

Conversion between Fahrenheit and Celsius

If we know Celsius and want Fahrenheit

$$F = \frac{9}{5}C + 32$$

If we know Fahrenheit and want Celsius

$$\mathrm{C} = \frac{5}{9}(F - 32)$$

Absolute or Kelvin Scale

- The lowest possible temperature on the Celsius Scale is 273°C.
- The Kelvin Scale just takes this value and calls it 0K, or absolute zero.
- To convert from C to K just add 273.

$$K=C+273$$

First Law of Thermodynamics

- The change in the *internal energy* (ΔE) of a thermodynamic system is equal to the amount of *heat energy* (*q*) added to or lost by the system plus *work done* (*w*) on or by the system.

$$\Delta E = q + w$$

Values of Thermodynamic Functions

- $\Delta E = q + w;$
  - *q* is assigned a *positive* value if *heat is absorbed*, but a *negative* value if *heat is lost* by the system;
  - *w* is assigned a *positive* value if *work is done on*, but a *negative* value if *work is done by* the system.
  - For processes that do not involve phase changes, positive ΔE results in temperature increase.

Entropy

- Thermodynamic function that describes the number of arrangements that are available to a system existing in a given state.

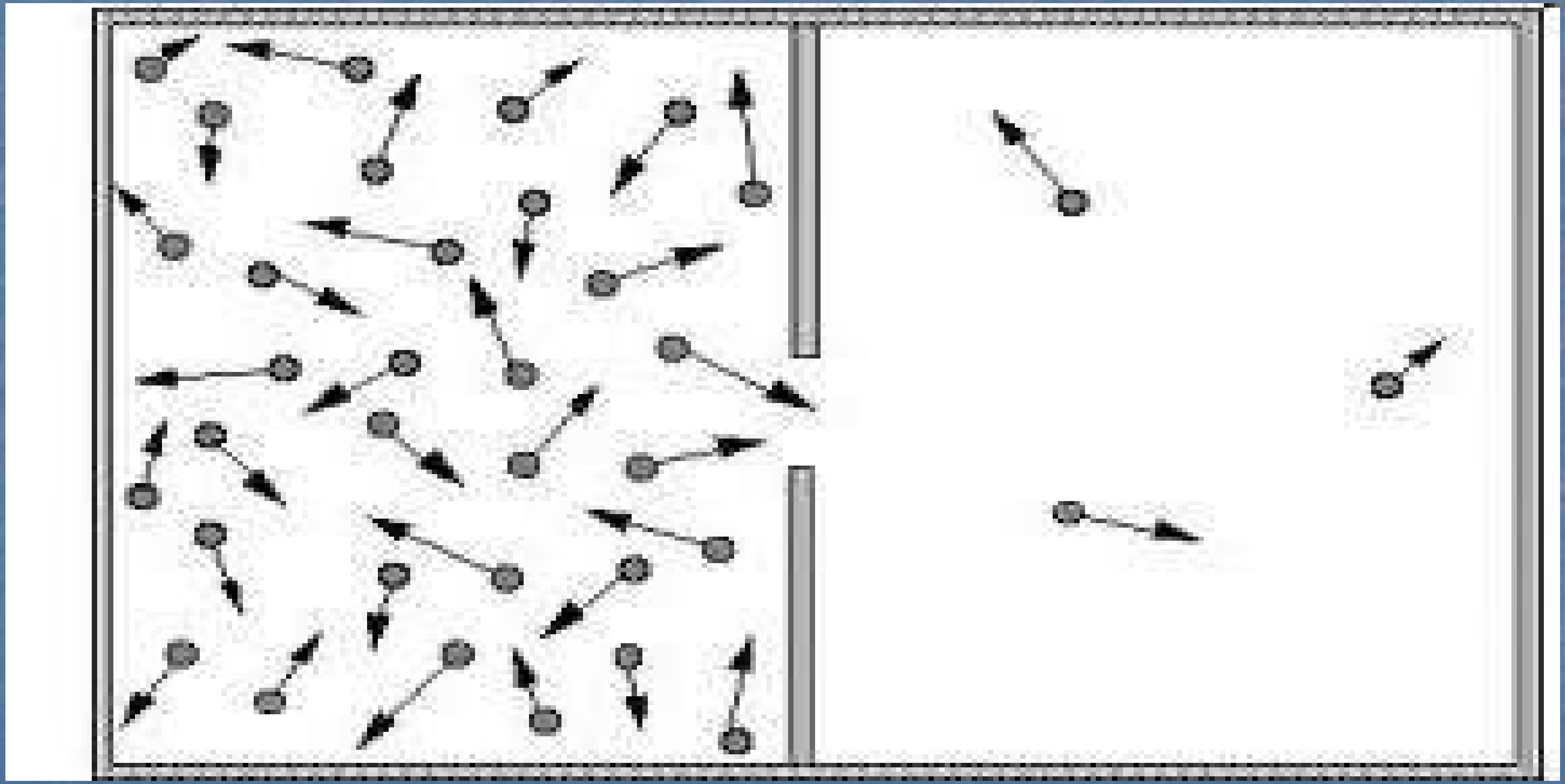
What is Entropy?

- A thermodynamic (*energy*) function that describes the degree of ***randomness*** or ***probability*** of existence.
- As a *state function* – entropy change depends only on the initial and final states, but not on how the change occurs.

What is the significance of *entropy*?

- Nature spontaneously proceeds toward the state that has the highest probability of (energy) existence – highest entropy
- Entropy is used to predict whether a given process/reaction is thermodynamically possible;

Where do molecules have the higher entropy



Relative Entropy of Substances

- Entropy:
  - increases from solid to liquid to vapor/gas;
  - increases as temperature increases;
  - of gas increases as its volume increases at constant temperature;
  - increases when gases are mixed.
  - of compound increases as its structure becomes more complex.

Second Law of Thermodynamics

- In any spontaneous process there is always an increase in the entropy of the universe.
- The entropy of the universe is increasing.
- The total energy of the universe is constant, but the entropy is increasing.

$$\otimes S_{universe} = \otimes S_{system} + \otimes S_{surroundings}$$

Third Law of Thermodynamics

- The entropy of a perfect crystal at 0 K is zero.
- The entropy of a substance increases with temperature.

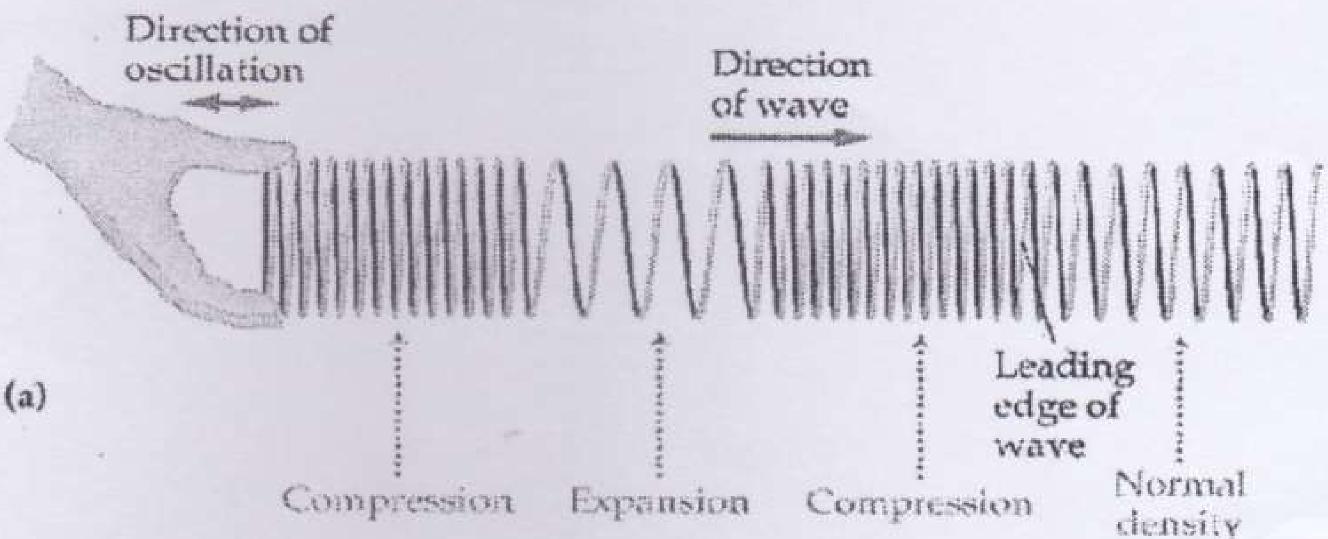
Lecture 3 of biophysics

Sound and Hearing

- What is the sound
- Speed of sound
- Reflecting sound
- The ear and hearing

Physics of hearing
Sound Waves

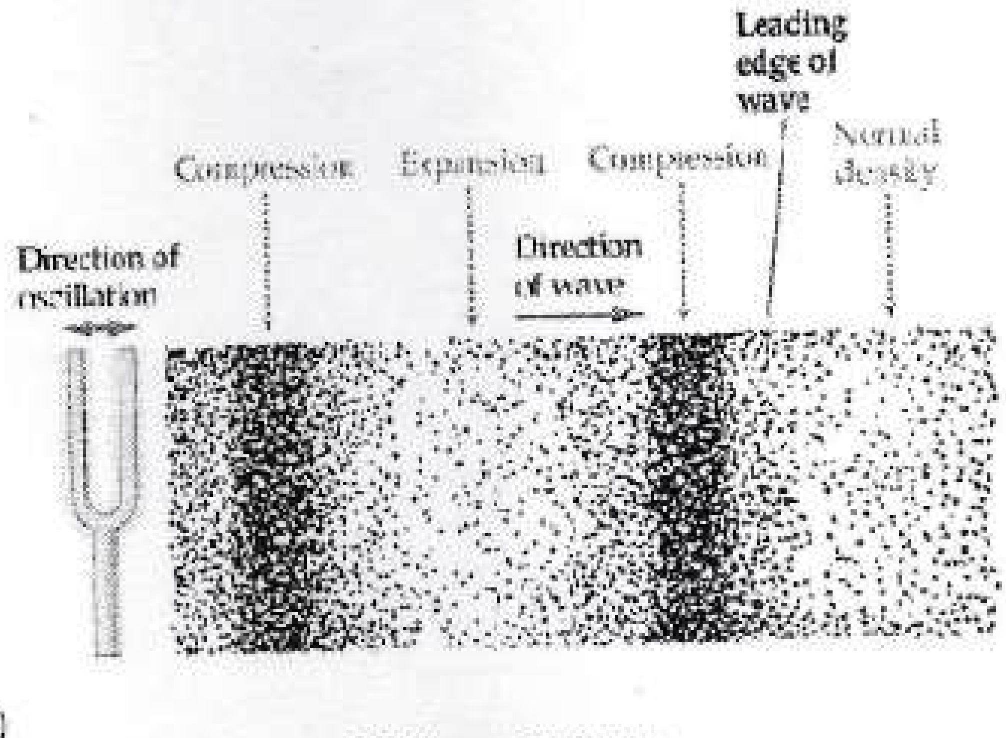
- Sound waves are longitudinal waves
- They travel through any material medium
- The speed of the wave depends on the properties of the medium
- If you oscillate one end of a coiled spring, such as the one shown in the figure below, back and forth, you will see a longitudinal wave moving away from you.

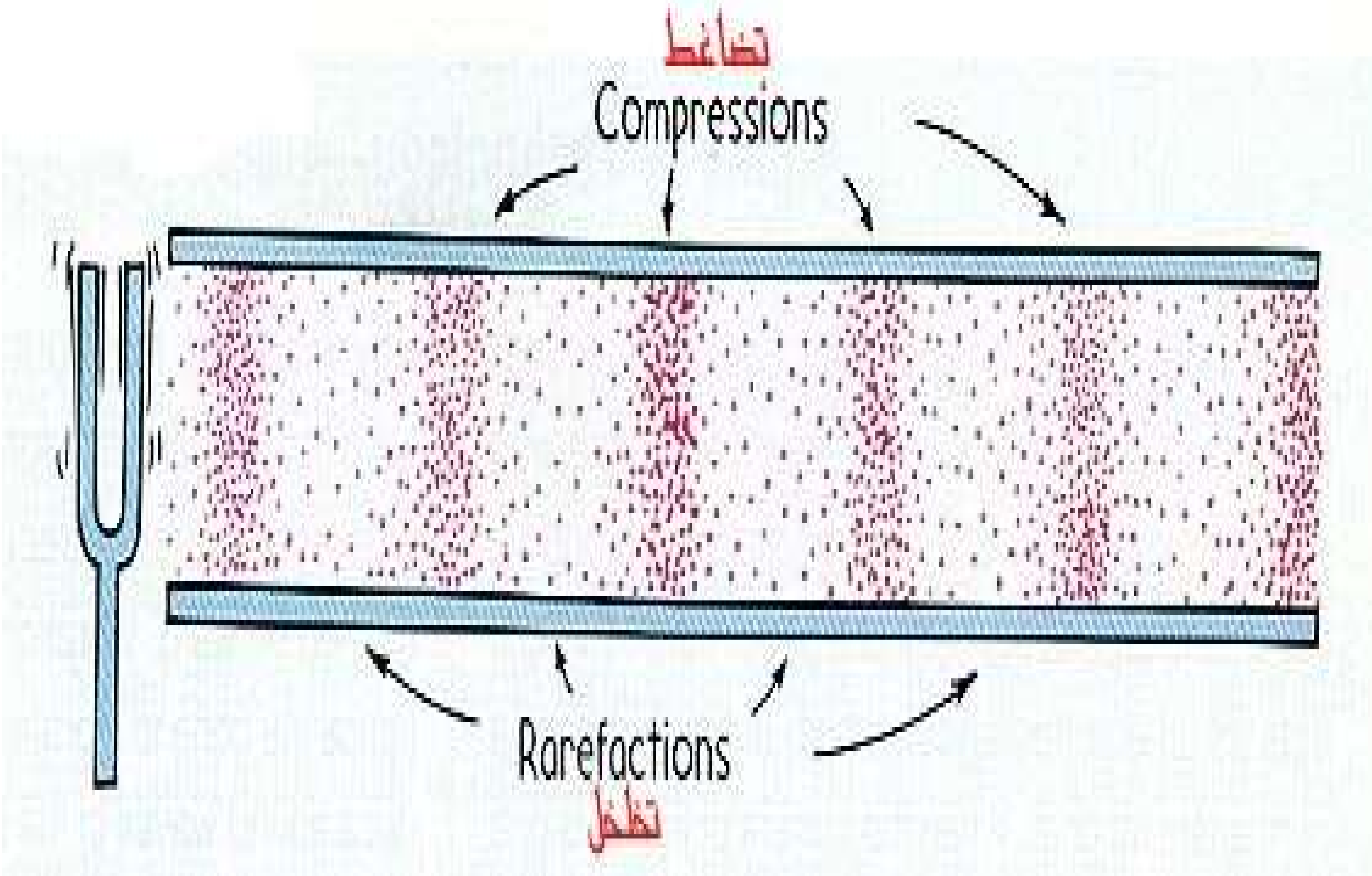


(a)

Sound Waves and Beats

- Similarly, the figure below shows how a vibrating tuning fork produces sound waves as its tines oscillate back and forth. Just as with a coiled spring, a wave travels away from its vibrating source.




تضاغط
Compressions
Rarefactions
تخلخل

Periodic Sound Waves

- A compression moves through a material as a pulse, continuously compressing the material just in front of it
- The areas of compression alternate with areas of lower pressure and density called rarefactions
- These two regions move with the speed equal to the speed of sound in the medium

- In general, a sound wave is formed when an oscillating object creates alternating regions of compressed and expanded air. These alternating regions move away from the source as a longitudinal wave.

Sound Waves and Beats

- The speed of sound depends on the medium through which it is moving. In general, the speed of sound depends on the "stiffness" of a material.
- Because air is quite compressible and not very "stiff," the speed of sound is relatively low in air compared to liquids and solids.
- Water is not very compressible, and the speed of sound in it is about 4 times greater than in air. Sound travels even faster in solids than in liquids. In fact, the speed of sound in steel is about 17 times greater than in air.

Sound Waves and Beats

- The following table gives the speed of sound in a range of materials.

Table 14.1 Speed of Sound in Various Materials

Material	Speed (m/s)
Aluminum	6420
Granite	6000
Steel	5960
Pyrex glass	5640
Copper	5010
Plastic	2680
Fresh water (20 °C)	1482
Fresh water (0 °C)	1402
Hydrogen (0 °C)	1284
Helium (0 °C)	965
Air (20 °C)	343
Air (0 °C)	331

Sound Waves and Beats

- The speed of sound is the same in all directions of travel and for all frequencies. Thus, the speed v remains constant in the wave speed equation:

speed = wavelength x frequency

$$v = f\lambda$$

Sound Waves and Beats

- Humans' sense of hearing detects only a small portion of the sound waves that are created in nature.
- As a rule of thumb, humans can hear sounds between 20 Hz on the low-frequency end and 20,000 Hz on the high-frequency end.
- Sounds with a frequency of less than 20 Hz are referred to infrasonic.
- Sounds with a frequency greater than 20,000 Hz are called ultrasonic.

Sound Waves and Beats

- Infrasound and ultrasound frequencies occur commonly in nature.
- Bats and dolphins produce ultrasound. They send out ultrasonic waves that reflect back to them from objects in their vicinity. The reflected sound waves—echoes—are used in a process known as echolocation to locate prey and to navigate.
- It was also recently learned that elephants communicate with one another using sounds with frequencies as low as 15 Hz.

Categories of Sound Waves

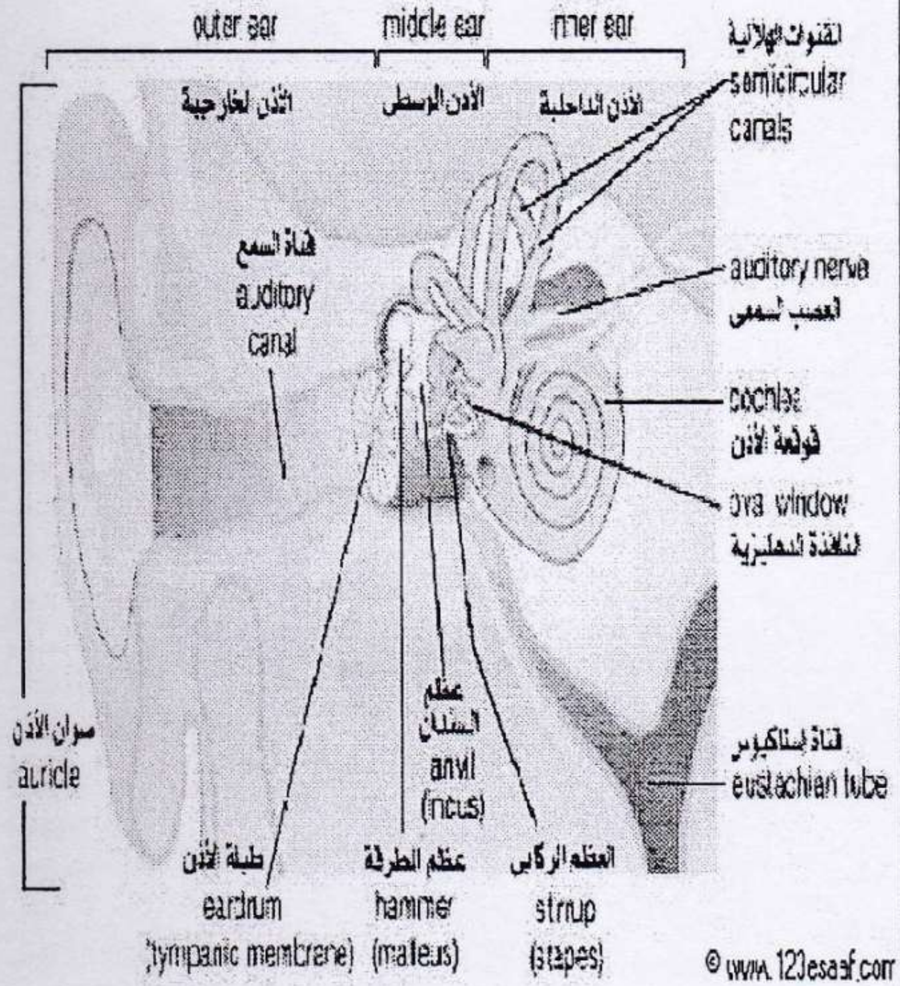
- The categories cover different frequency ranges
- **Audible waves** are within the sensitivity of the human ear
  - Range is approximately 20 Hz to 20 kHz
- **Infrasonic waves** have frequencies below the audible range
- **Ultrasonic waves** have frequencies above the audible range

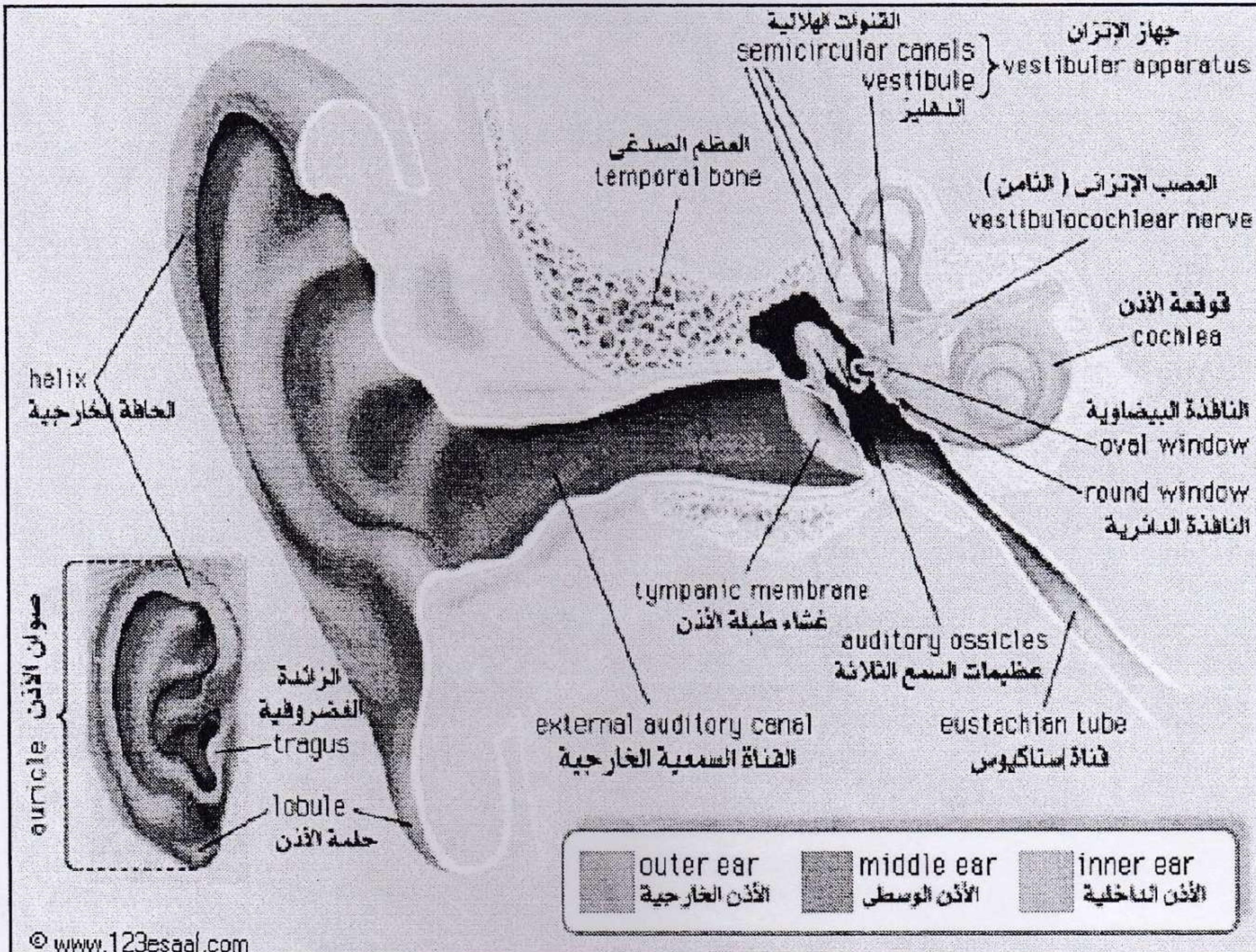
Three major divisions of human ear

1. The outer ear
   - pinna or auricle
   - ear canal
   - eardrum

2. The middle ear
   - three ossicle bones; (malleus, incus, stapes)
   - two major muscles (stapedial muscle, tensor tympani)
   - Eustachian tube

3. The inner ear
   - Vestibule
   - Semicircular Canals
   - Cochlea





القنوات الهلالية
semicircular canals
vestibule
الدهليز
جهاز الإتزان
vestibular apparatus
العظم الصدغي
temporal bone
العصب الإتزاني (الثامن)
vestibulocochlear nerve
قوقعة الأذن
cochlea
helix
الحافة الخارجية
الناقذة البيضاوية
oval window
round window
الناقذة الدائرية
tympanic membrane
غشاء طبلة الأذن
auditory ossicles
عظيمات السمع الثلاثة
صيوان الأذن
auricle
الزائدة الغضروفية
tragus
lobule
حلمة الأذن
external auditory canal
القناة السمعية الخارجية
eustachian tube
قناة إستاكيوس
outer ear
الأذن الخارجية
middle ear
الأذن الوسطى
inner ear
الأذن الداخلية
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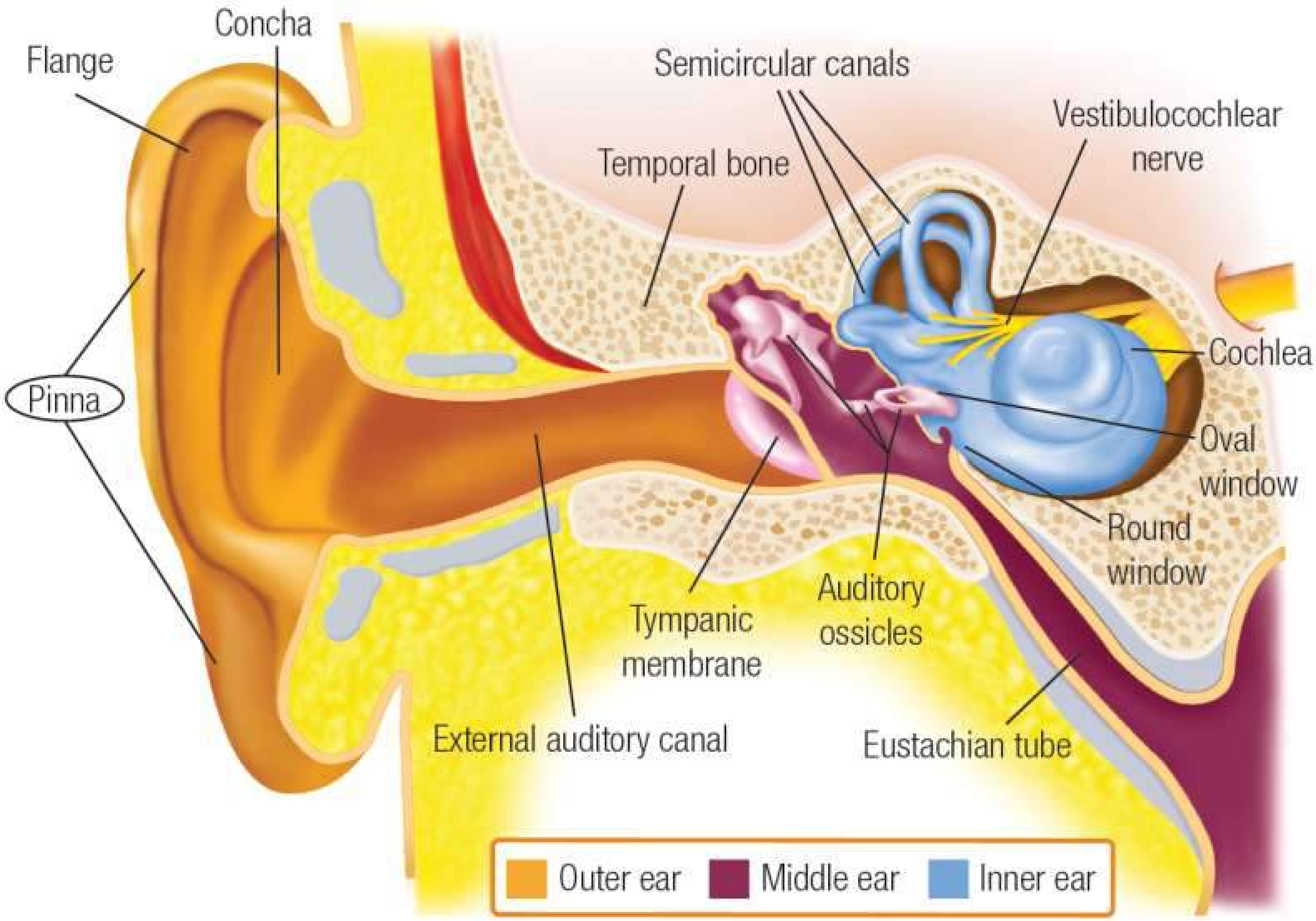
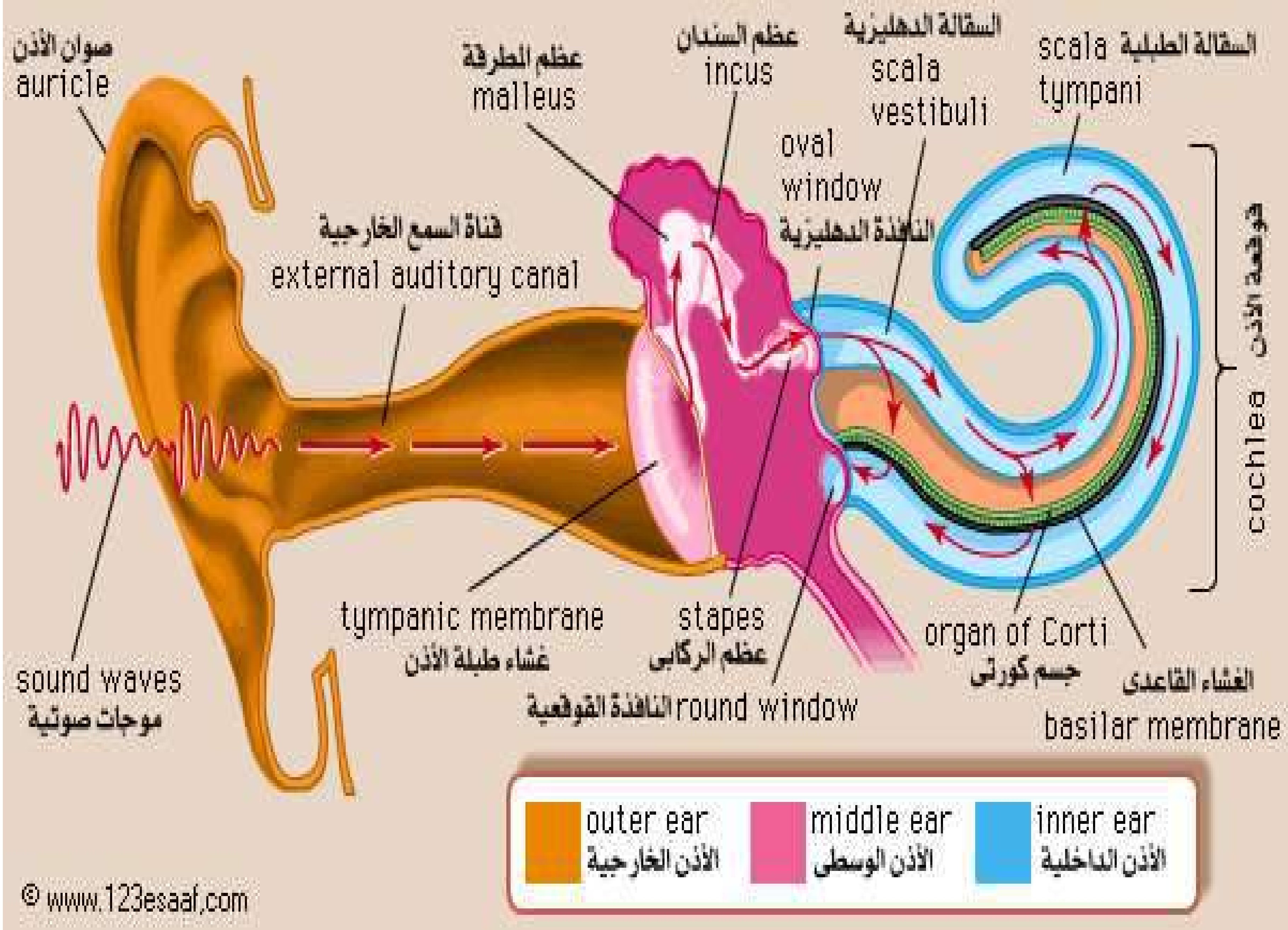
Gross Anatomy of the Ear





صوان الأذن
auricle
عظم المطرقة
malleus
عظم السندان
incus
السقالة الدهليزية
scala
vestibuli
السقالة الطبلية
scala
tympani
oval
window
النافذة الدهليزية
قناة السمع الخارجية
external auditory canal
قوقعة الأذن
cochlea
tympanic membrane
غشاء طبلة الأذن
stapes
عظم الركابى
organ of Corti
جسم كورتى
sound waves
موجات صوتية
النافذة القوقعية
round window
الغشاء القاعدى
basilar membrane
outer ear
الأذن الخارجية
middle ear
الأذن الوسطى
inner ear
الأذن الداخلية
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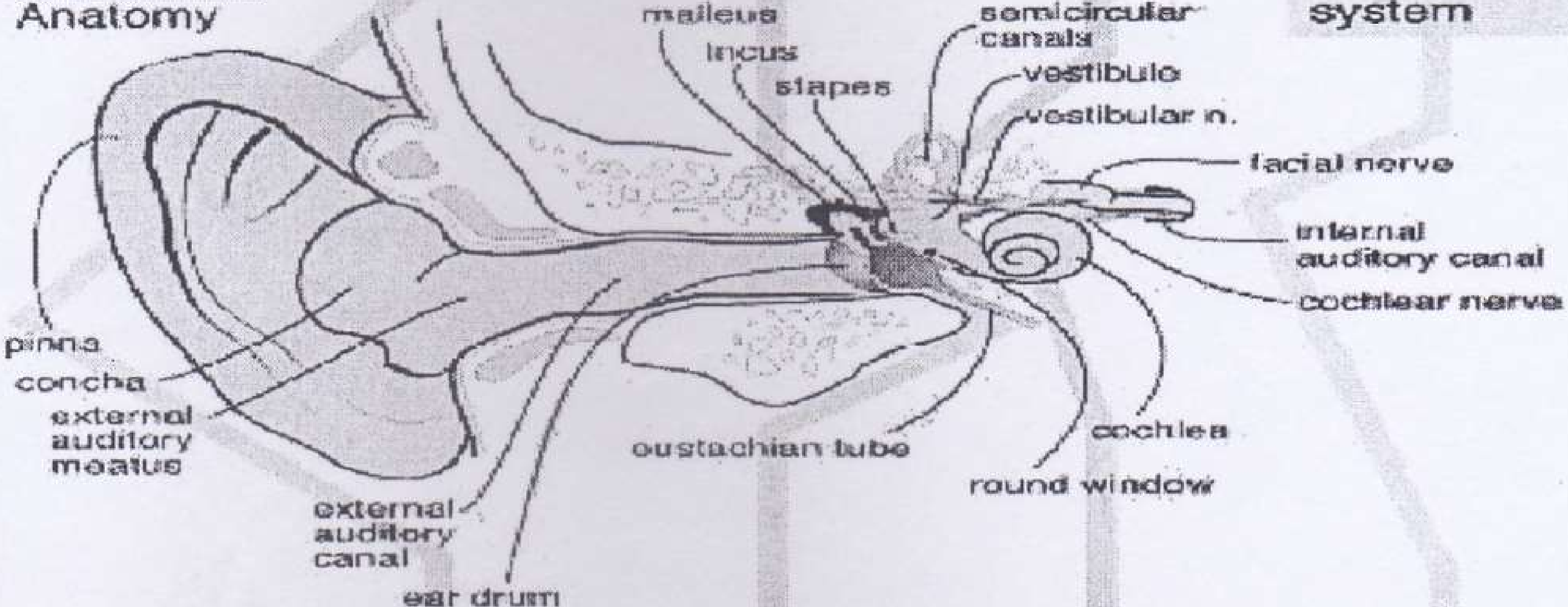
Four major divisions of auditory system – Function

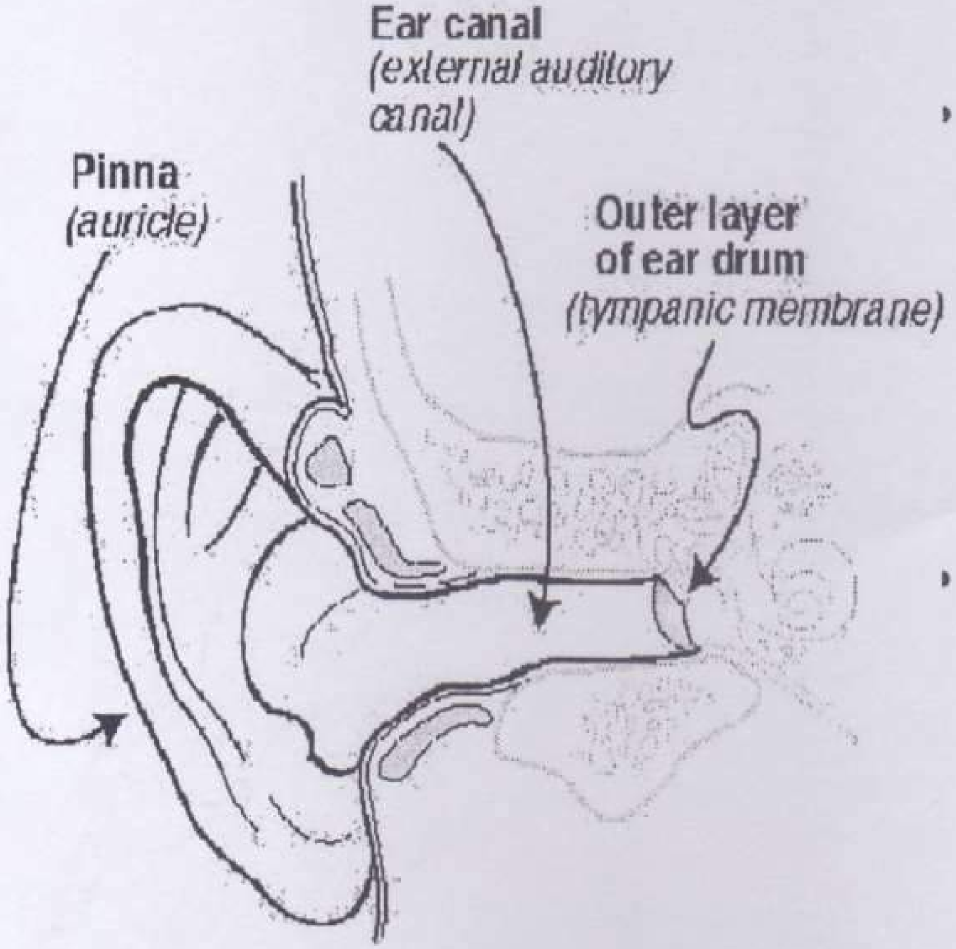
Gross division	Outer ear	Middle ear	Inner ear	Central auditory nervous system

Anatomy



	Outer ear	Middle ear	Inner ear	Central auditory nervous system
Mode of operation	•air vibration	•mechanical vibration	•mechanical •hydrodynamic •electrochemical	•electrochemical
Function	•protection •amplification •localization	•impedance matching •selective oval window stim. •pressure equalization	•filtering distribution •transduction	•information processing

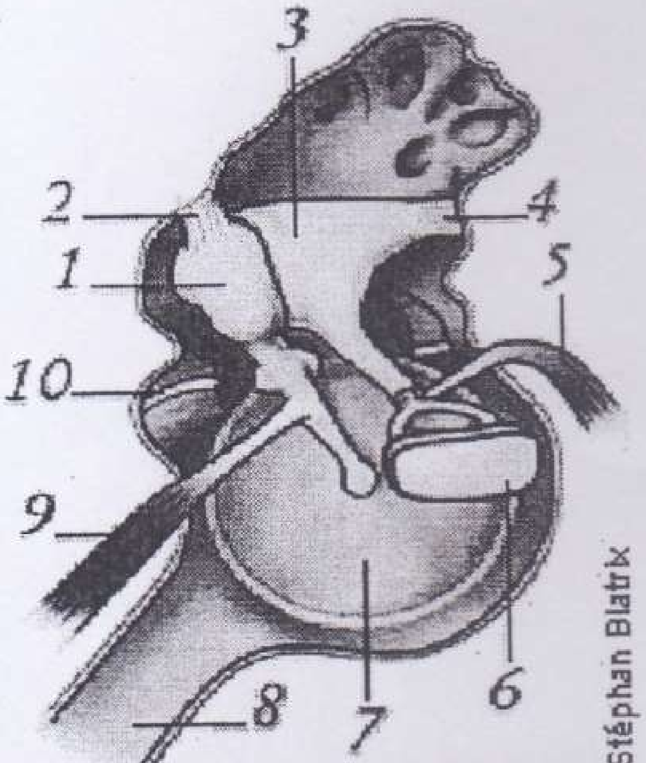
I. Outer ear

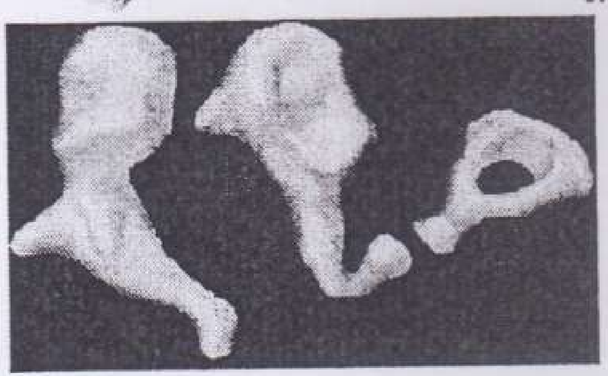


Outer Ear

- Three parts of outer ear
  1) Pinna
  2) Ear canal
  3) Ear drum
- Major function of outer ear
  1) protection
  2) amplification
  3) sound localization

II. Middle ear





- **Three main parts of middle ear**

(1) Three Ossicle bones:

- Malleus(1), Incus(3), Stapes(6)

Function) Impedance matching

(2) Two muscles

- Stapedial muscle(5)
- Tensor tympani(9)

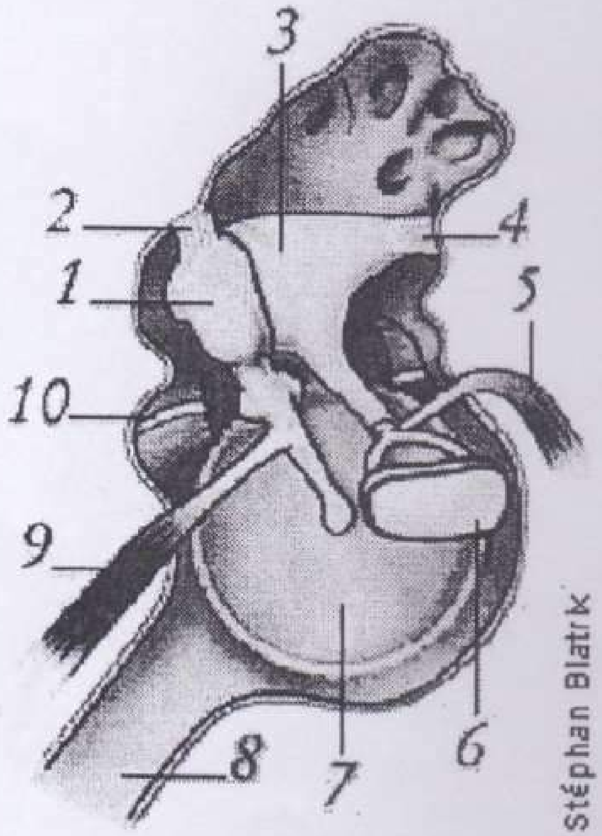
Function) Protection

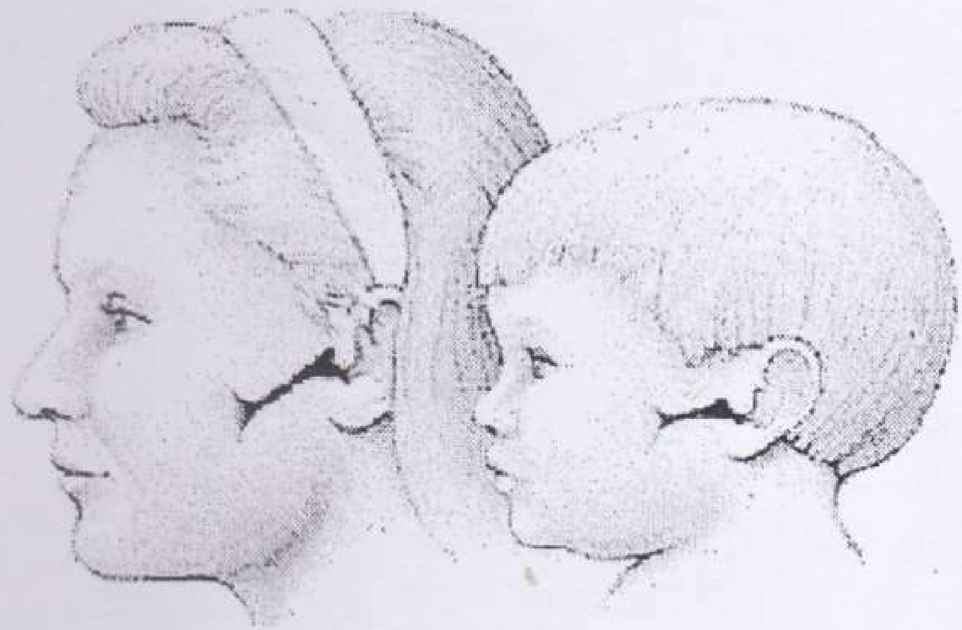
(3) Eustachian tube(8)

Function) Equalizer of air pressure

II. Middle ear (3) Eustachian Tube

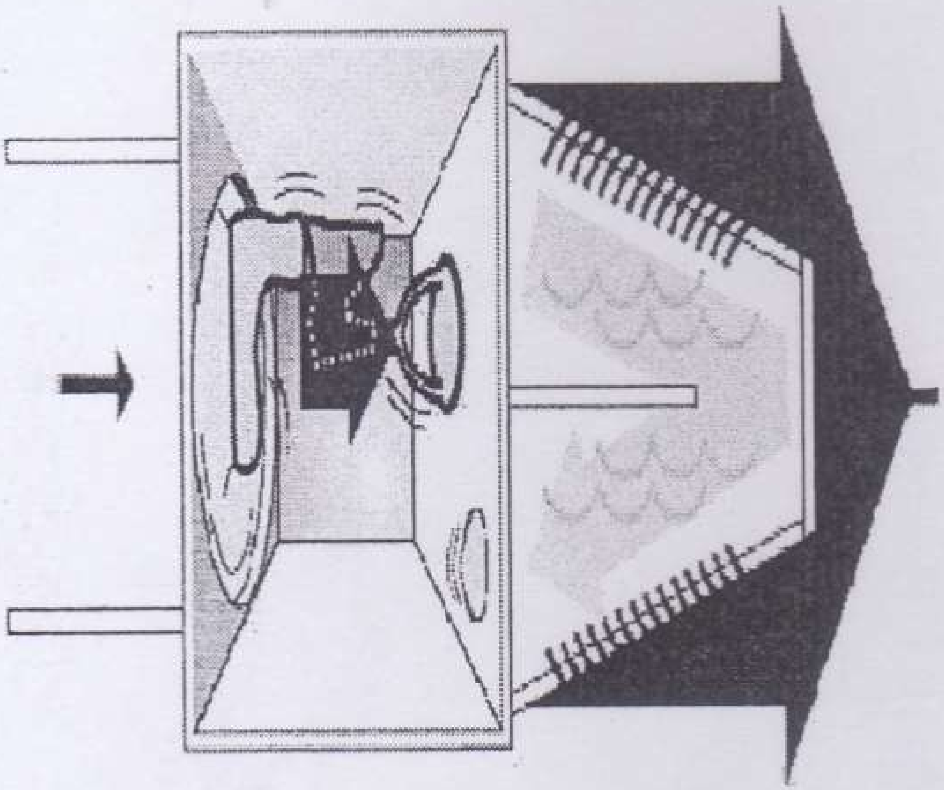
- Comparison of Eustachian tubes In adults and children
  : shorter, smaller, less steep eustachian tube in children
  => Hard to be drained away from middle ear





II. Middle ear

- Middle ear cavity



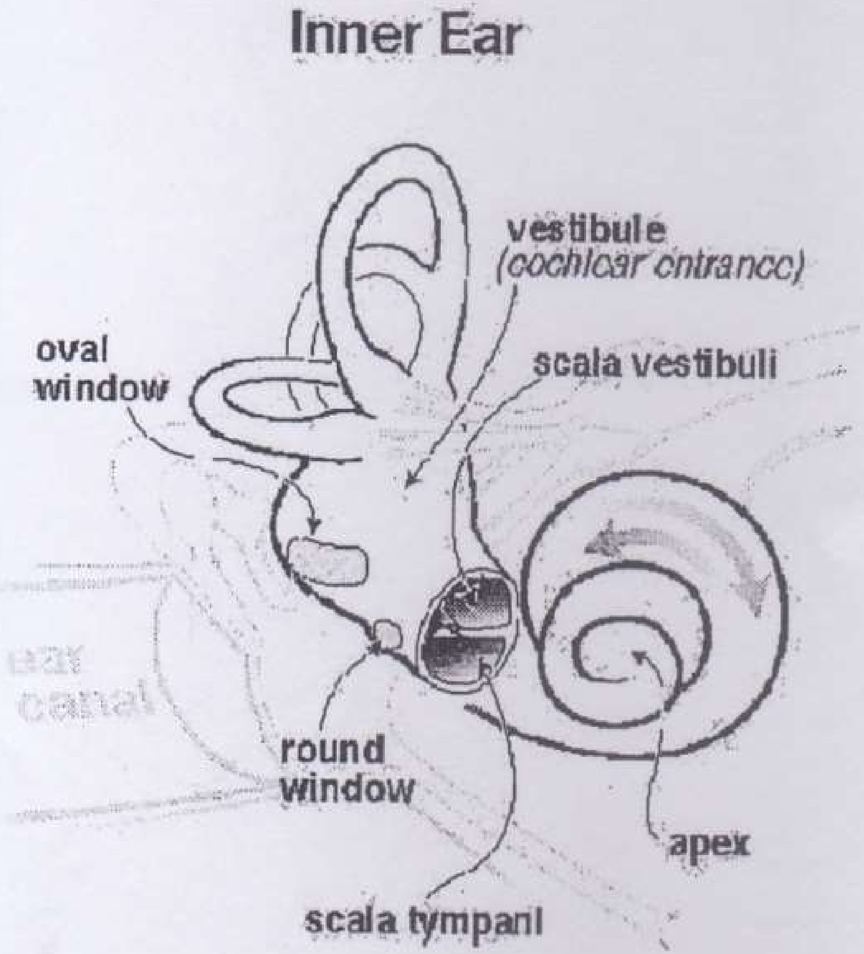
- **Function of ossicles**

  - 99.9% sound is reflected due to high impedance of fluid in the cochlea (0.1% sound is only passed = - 30 dB sound loss from air - fluid impedance mismatch)

  - Middle ear bones overcome the loss of sound by increasing sound pressure (+34dB)

  => **Impedance matching**

III. Inner ear

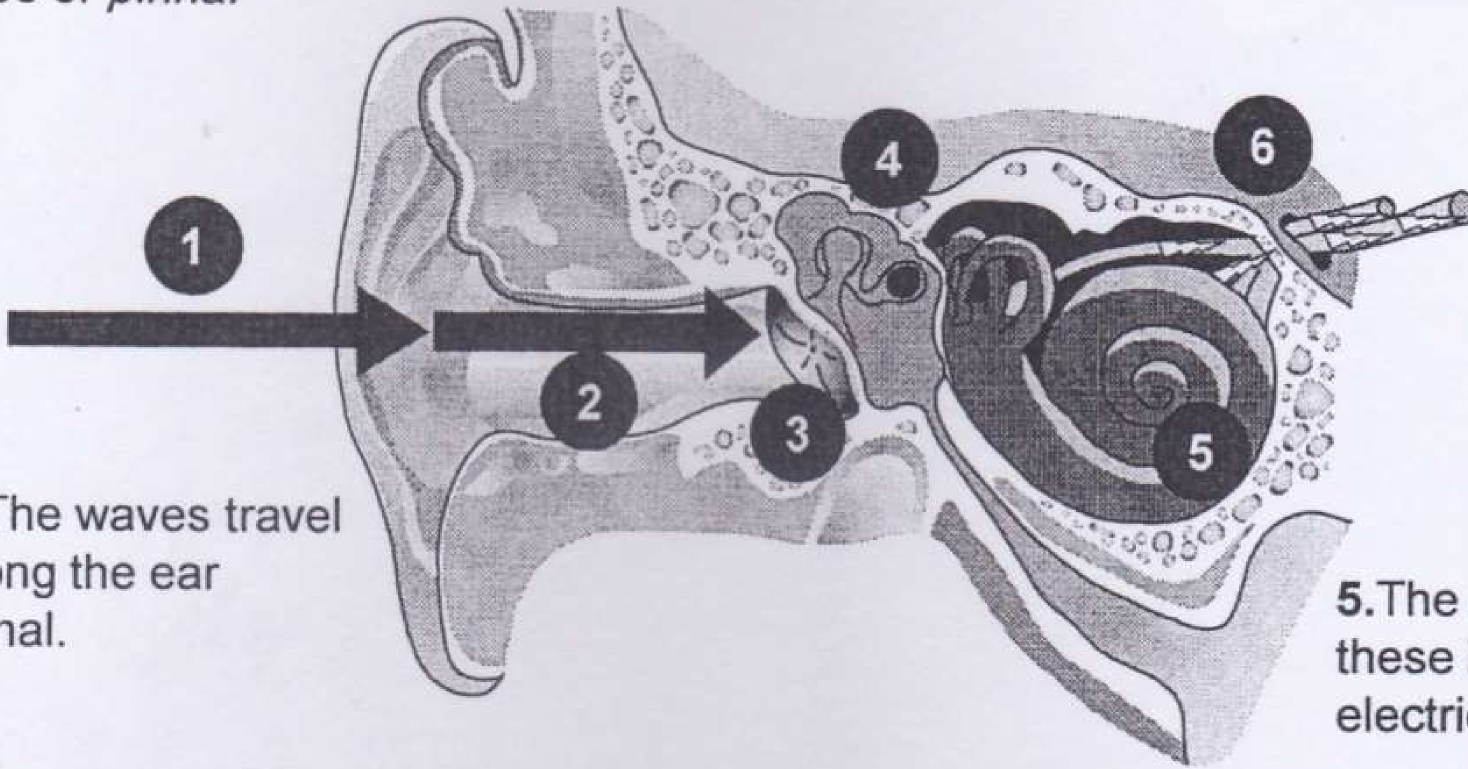


- **Twp parts of inner ear**
  1) Cochlea (Hearing)
     - Scala vestibuli
     - Scala media
     - Scala tympani
  2) Vestibular system (balance)
- **Major function of inner ear**
  1) Hearing
  (It transmits sound to neural impulse and gives resonant frequency)
  2) Balance

How does the ear hear?

1.Sound waves are collected by the ear lobe or *pinna.*

6.The auditory nerve takes the signals to the brain.



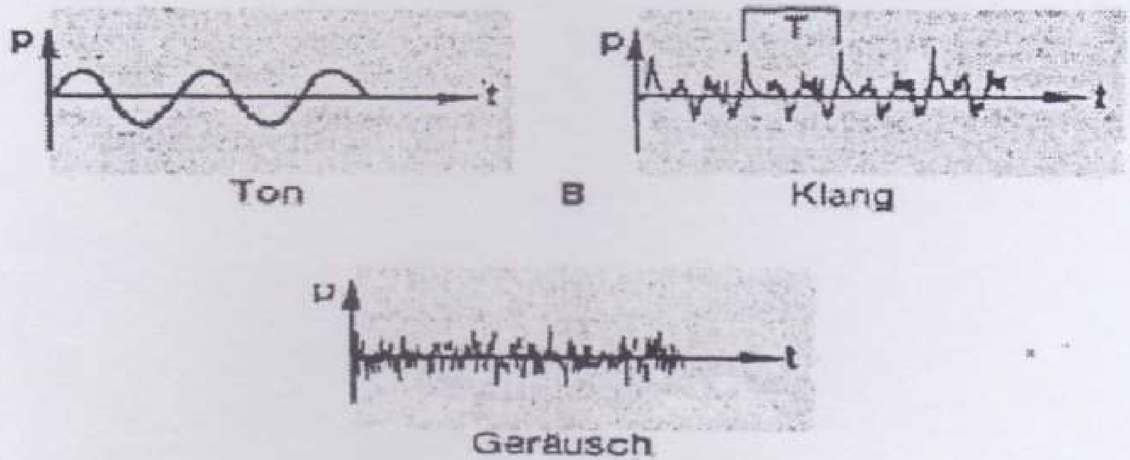
2.The waves travel along the ear canal.

5.The cochlea turns these into electrical signals.

3.The waves make the ear drum vibrate.

4.The small bones (ossicles) amplify the vibrations.

The ear is the body's main receiver system for acoustic wave information. The main objective of the ear is to receive, the acoustic waves, to amplify the intensity, to analyze the frequency and intensity structure of the wave, and to reject random background noise.



The auditory system of the body is structured into a:

- Mechanical system, to catch and to amplify acoustical information (ear);
- Sensory (electrical) system which converts mechanical pulses into electrical signals which are passed on by the auditory nerves to the brain;
- Auditory system, to decode and analyse the electrical nerve signals in the auditory cortex (brain).

Pathway of a Sound Wave

- The sound waves arrive at the pinna (auricle), the only visible part of the ear.
- Once the sound waves have passed the pinna, they move into the auditory canal (external acoustic meatus) before hitting the tympanic membrane (eardrum).
- Once the sound waves reach the tympanic membrane, it begins to vibrate and they enter into the middle ear.
- The vibrations are transmitted further into the ear via three bones (ossicles): malleus hammer), incus (anvil), and the stapes (stirrup). These three bones form a bridge from the tympanic membrane to the oval window

Pathway of a Sound Wave

- Once sound passes through the oval window, it enters into the cochlea in the inner ear
- The cochlear nerve then transmits electrical impulses to the auditory region of the brain in the temporal lobe.
-

Lecture 4 of biophysics

biophysics

Human Circulatory System

Heart and Blood Vessels

INTRODUCTION

- The cardiovascular system is transport system of body
- It comprises blood, heart and blood vessels.
- The system supplies nutrients to and remove waste products from various tissue of body.
- The conveying media is liquid in form of blood which flows in close tubular system.

FUNCTION OF CARDIOVASCULAR SYSTEM

- Transport nutrients, hormones
- Remove waste products
- Gaseous exchange
- Immunity
- Blood vessels transport blood
  - Carries oxygen and carbon dioxide
  - Also carries nutrients and wastes
- Heart pumps blood through blood vessels

The Human Circulatory System

Humans have a double circulatory system i.e.

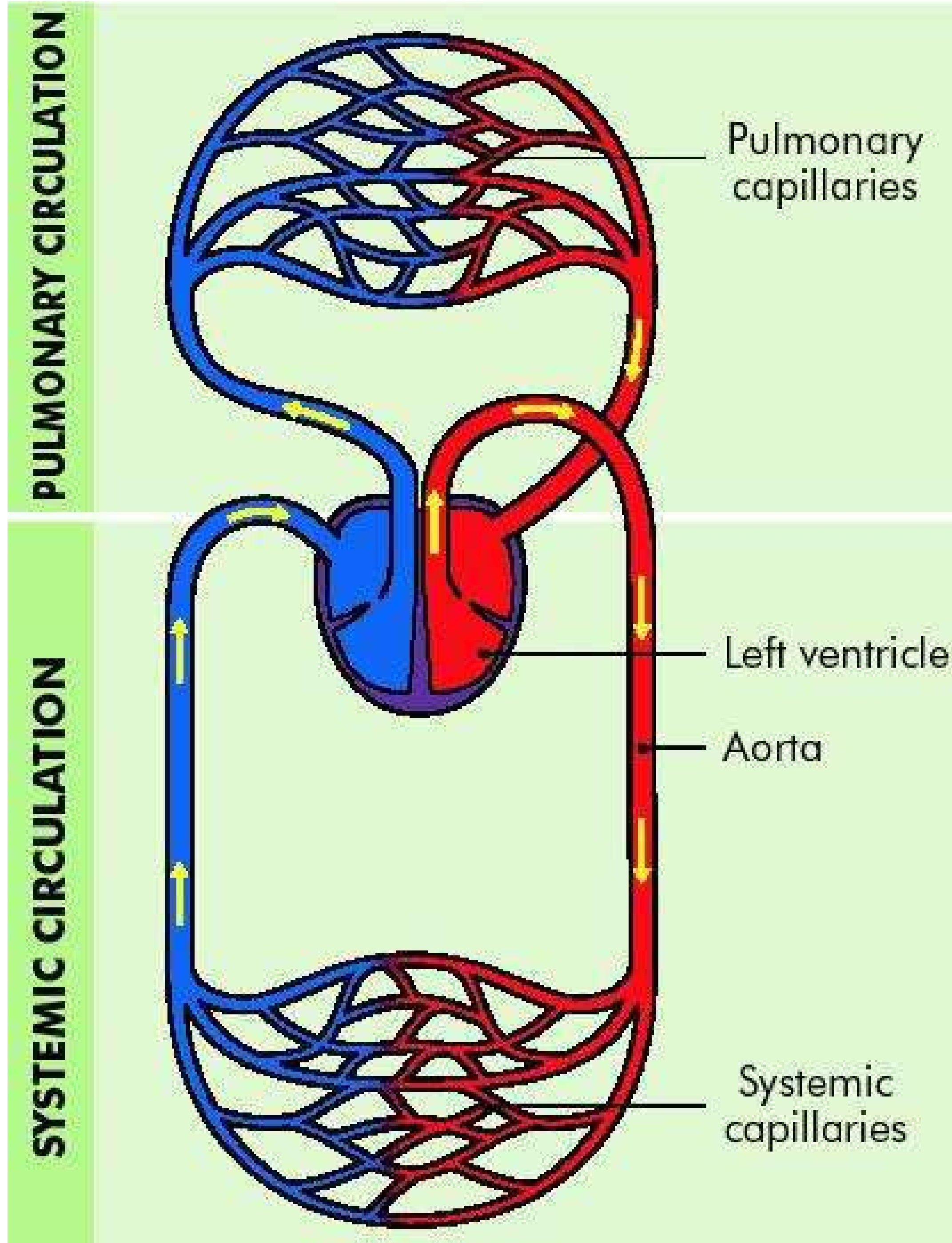
blood is pumped from the heart to the lungs and back to the heart

This is pulmonary circulation

and from the heart to the body and back to the heart

This is systemic circulation

Double circulation in humans



Separate systems

- Heart divided by a muscular wall into left and right sides
- Right side pumps deoxygenated blood to the lungs (pulmonary)
- Left side pumps oxygenated blood to the body (systemic)

Advantage of double circulatory system is adequate blood pressure ensured for both systems.

Blood vessels

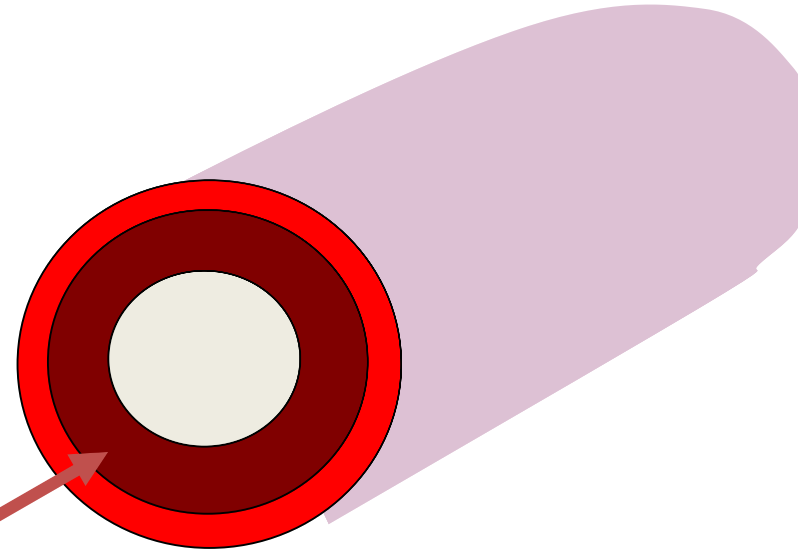
There are three types of blood vessels :-

- Arteries
- Veins
- Capillaries

The ARTERY

Arteries carry blood away from the heart.

the elastic fibres allow the artery to ***stretch*** under pressure



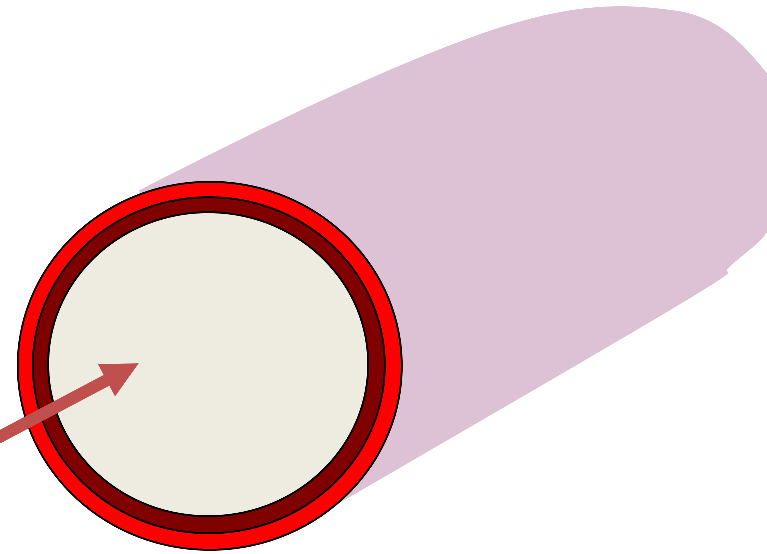
thick muscle and elastic fibres

the thick muscle can contract to ***push*** the blood along.

The VEIN

Veins carry blood towards from the heart.

veins have valves which act to stop the blood from going in the wrong direction.



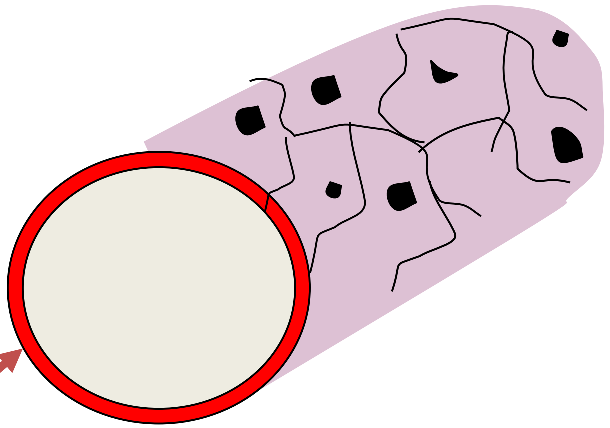
thin muscle and elastic fibres

body muscles surround the veins so that when they contract to move the body, they also squeeze the veins and push the blood along the vessel.

The CAPILLARY

Capillaries link Arteries with Veins

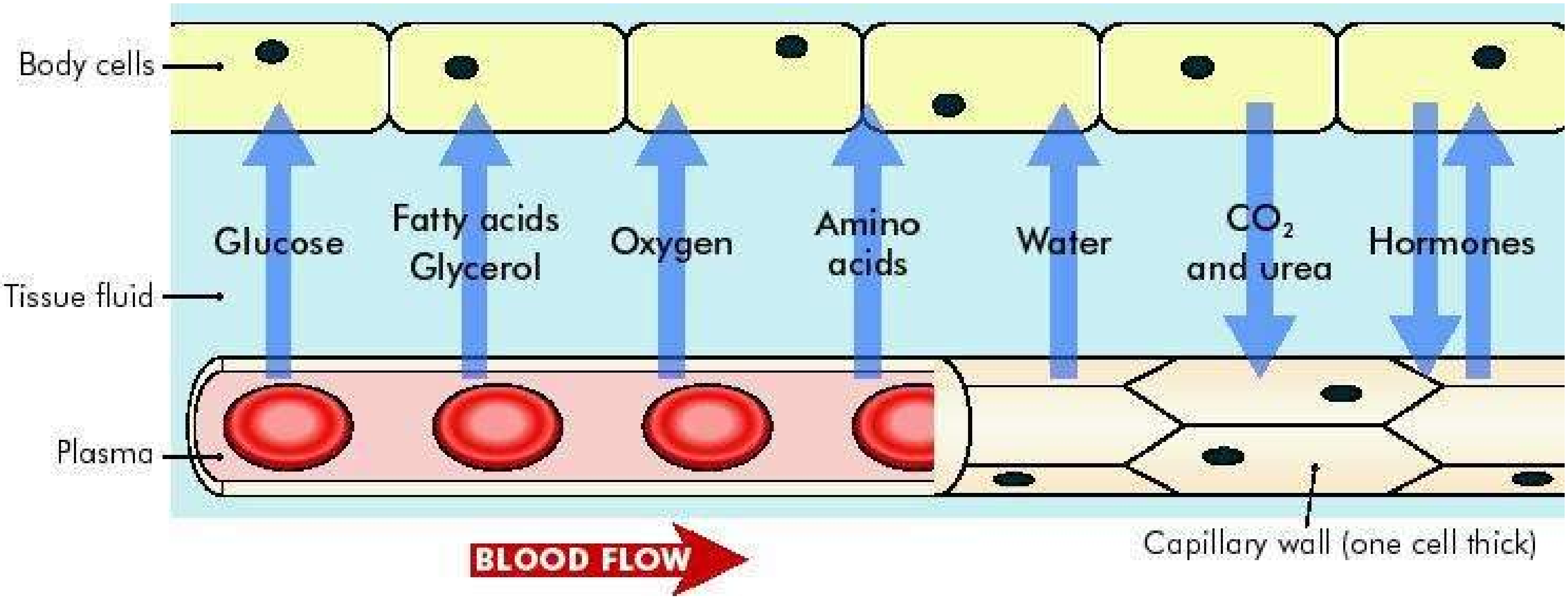
they exchange materials between the blood and other body cells.



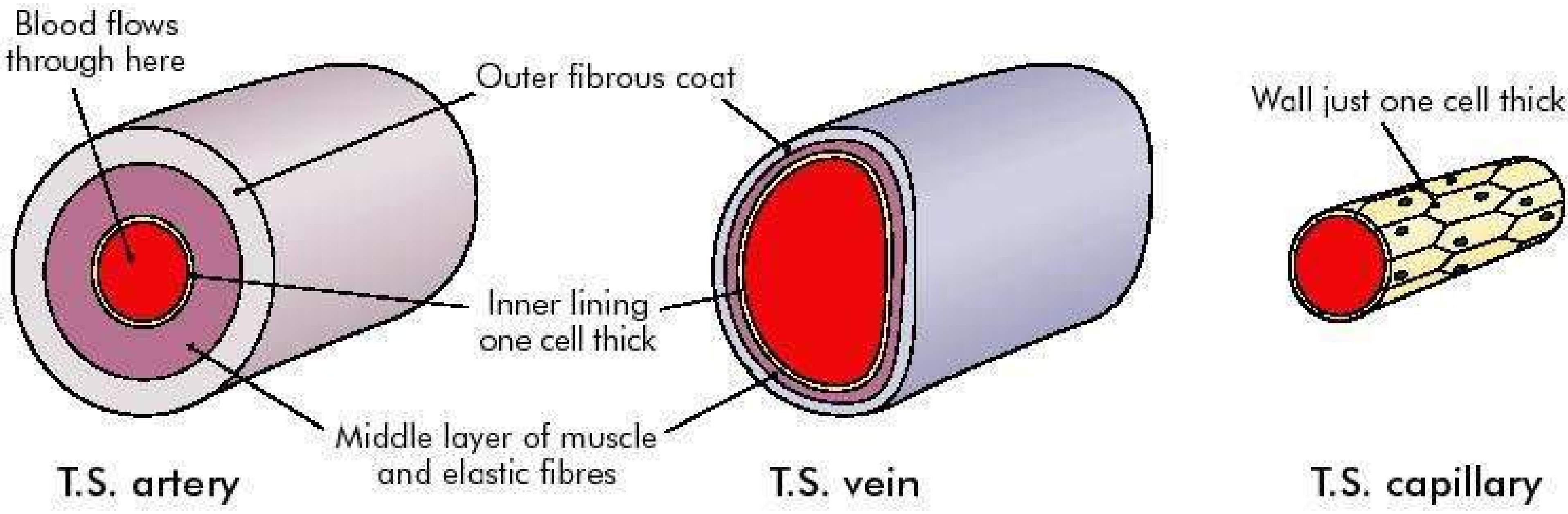
the wall of a capillary is only one cell thick

The exchange of materials between the blood and the body can only occur through capillaries.

Exchange of materials



The structure of the blood vessels



Differences between arteries, veins & capillaries

	Artery	Vein	Capillary
Structure	Thick, three-layered wall of muscle & elastic	Thin, three-layered wall of muscle & elastic	Wall only one cell thick
	Narrow lumen	Large lumen	Extremely narrow lumen
	No valves	Valves present	No valves
Function	Carry blood away from heart	Carry blood to heart	Allows exchange of materials between …
Blood flow	Rapid under pressure from heart	Sluggish under low pressure	Pressure reducing
	Blood flows in pulses	Blood flows steadily	

Portal blood system (1/3)

The pulmonary and systemic circulatory systems begin and end in the heart.

Pulmonary System (refer to a diagram)

Heart → Pulmonary Artery → Arterioles → Capillaries in lungs → Venules → Pulmonary Vein → Heart

Portal blood system (2/3)

Systemic System

Heart → Aorta → Arterioles → Capillaries in body organs → Venules → Veins → Heart

The Portal System begins and ends in capillaries e.g. hepatic portal system

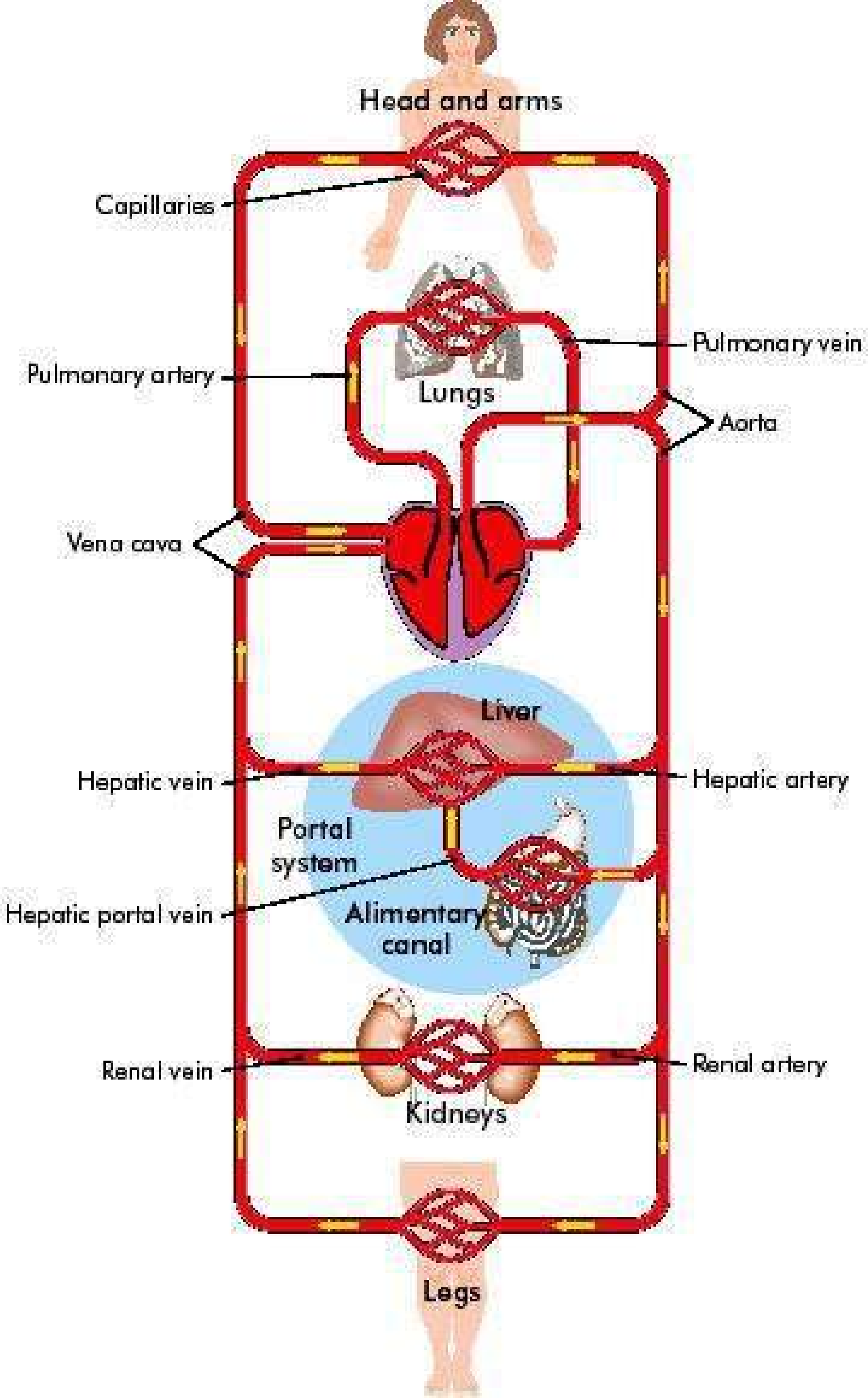
Capillaries (in stomach & intestines) → Venules → Hepatic Portal Vein → Venules → Capillaries (in the liver)

Portal blood system (3/3)

Usually blood flows

Artery → capillary → vein

The human circulatory system showing the portal system



The Heart

- Hollow muscular organ
- Slightly to the left of the sternum
- Above the diaphragm

Cardiac muscle

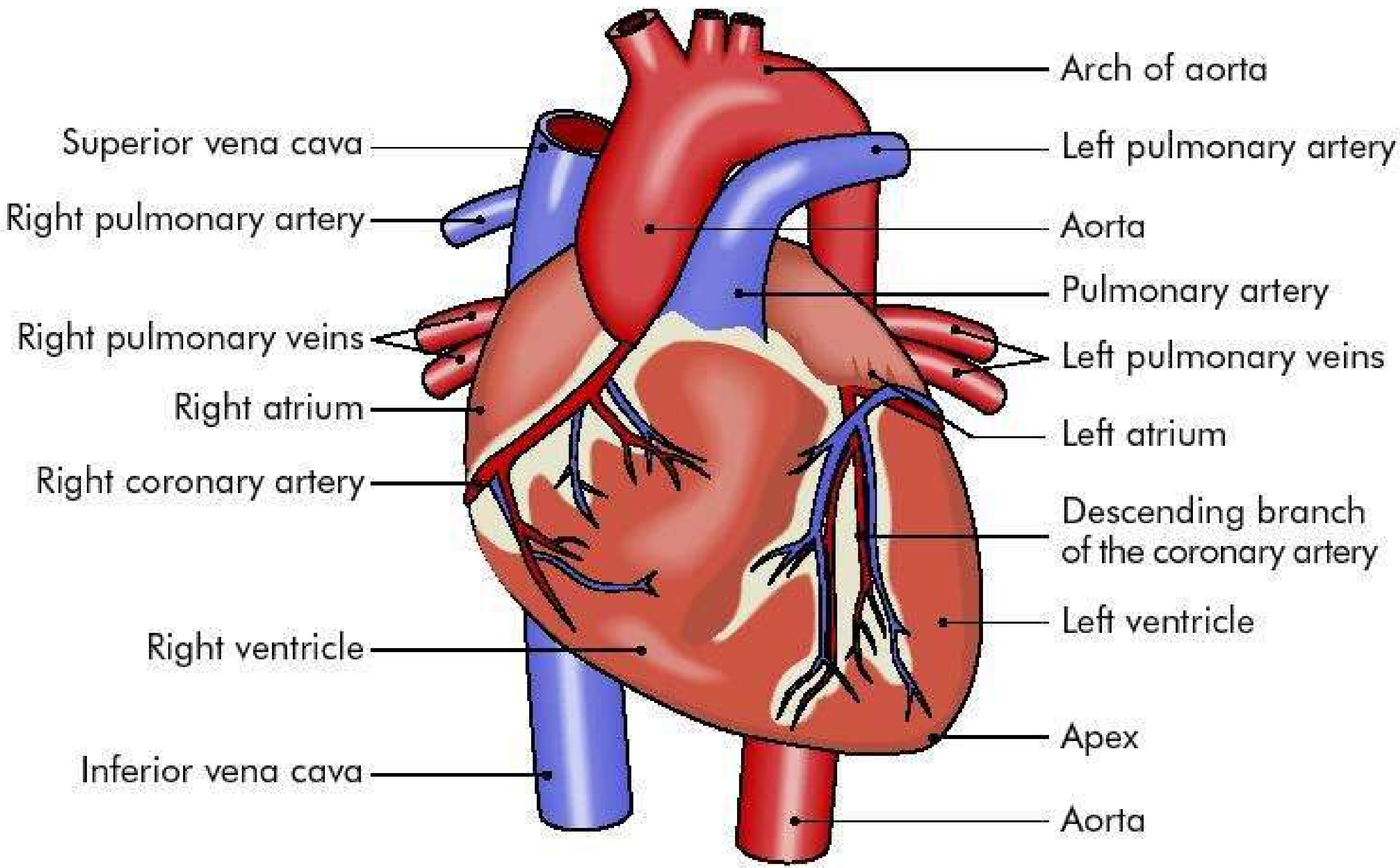
- Surrounded by fluid filled chamber (friction free movement) and protective sac = pericardium
- Heart wall made of cardiac muscle
- Contracts without nervous stimulation
- Approximately the size of your fist

Cardiac Blood Supply

Consists of the coronary blood vessels i.e.

- Coronary arteries bringing nutrients to the cardiac tissue from the aorta, and
- Coronary veins carry deoxygenated blood back to the right atrium
- Emerging from the heart are the aorta, vena cava, pulmonary arteries and veins.

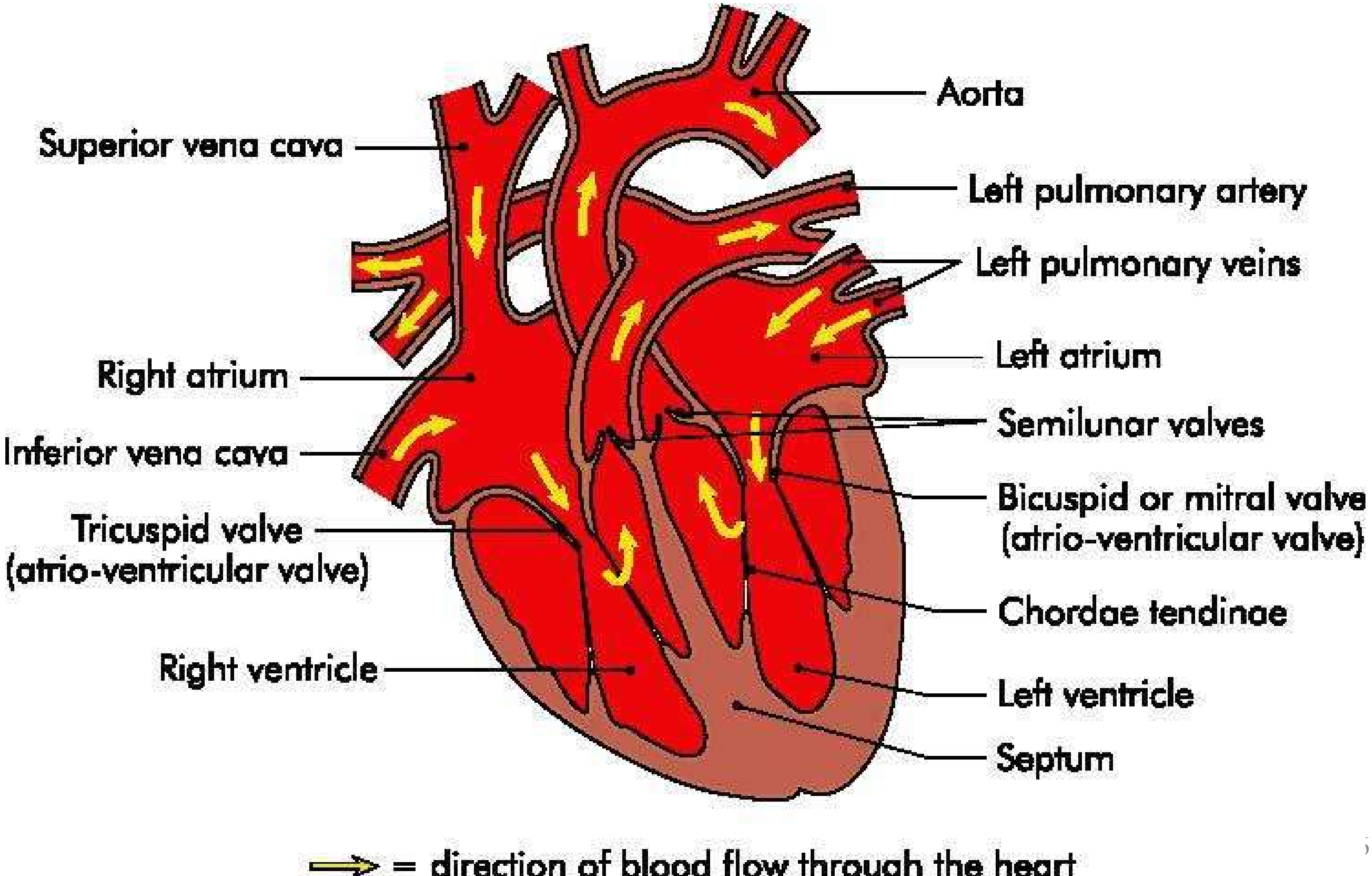
External view of human heart



Internal structure of heart

- Four chambers – 2 upper & 2 lower
- Two upper atria – thin walled
- Two lower ventricles – thick walled and larger than atria
- Divided vertically into left and right by wall – septum
- Blood does not flow through the septum

Diagram of internal heart structure



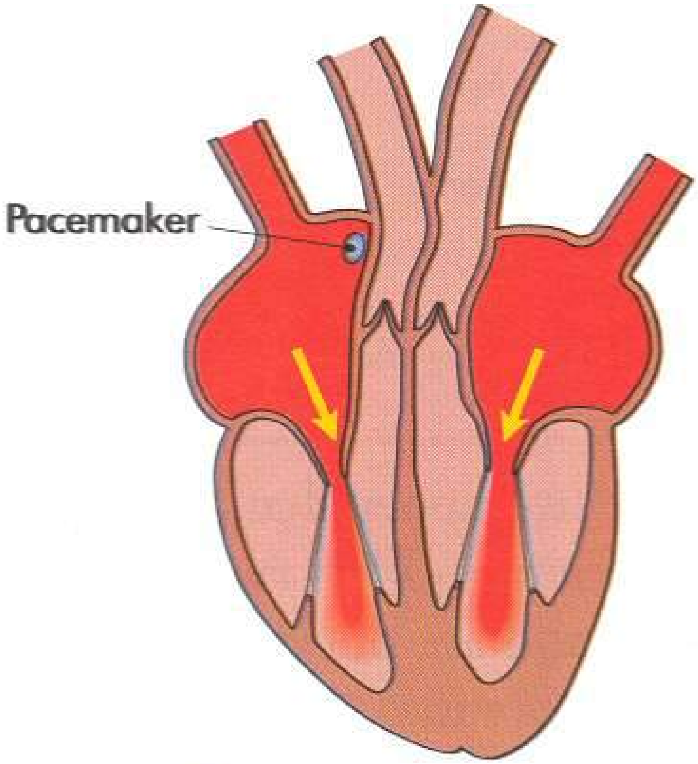
Valves in heart

Found at the exits of each chamber

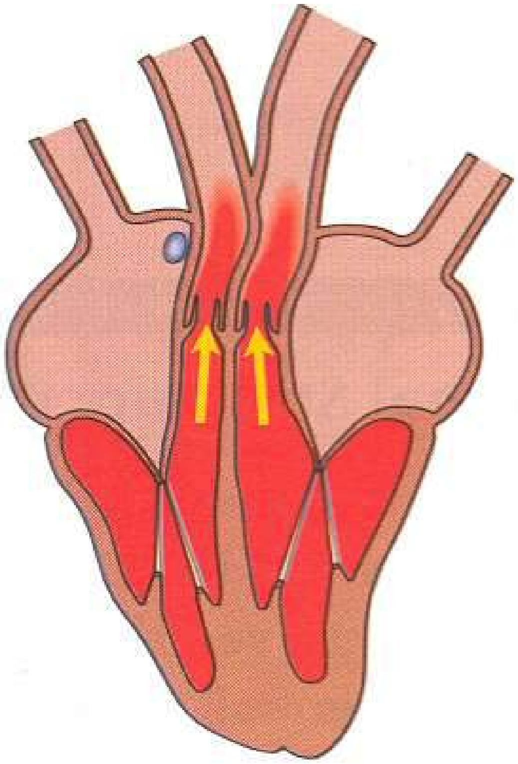
Four chambers → four valves

Function: to prevent a back flow of blood

Operation of valves in the heart



1 Ventricle muscles relax.
A-V valves open.
Semi-lunar valves close.
Blood flows from the atria into the ventricles.



2 Ventricle muscles contract.
A-V valves close.
Semi-lunar valves open.
Blood flows from the ventricles into the arteries leaving the heart.

How to draw the heart (1/6)

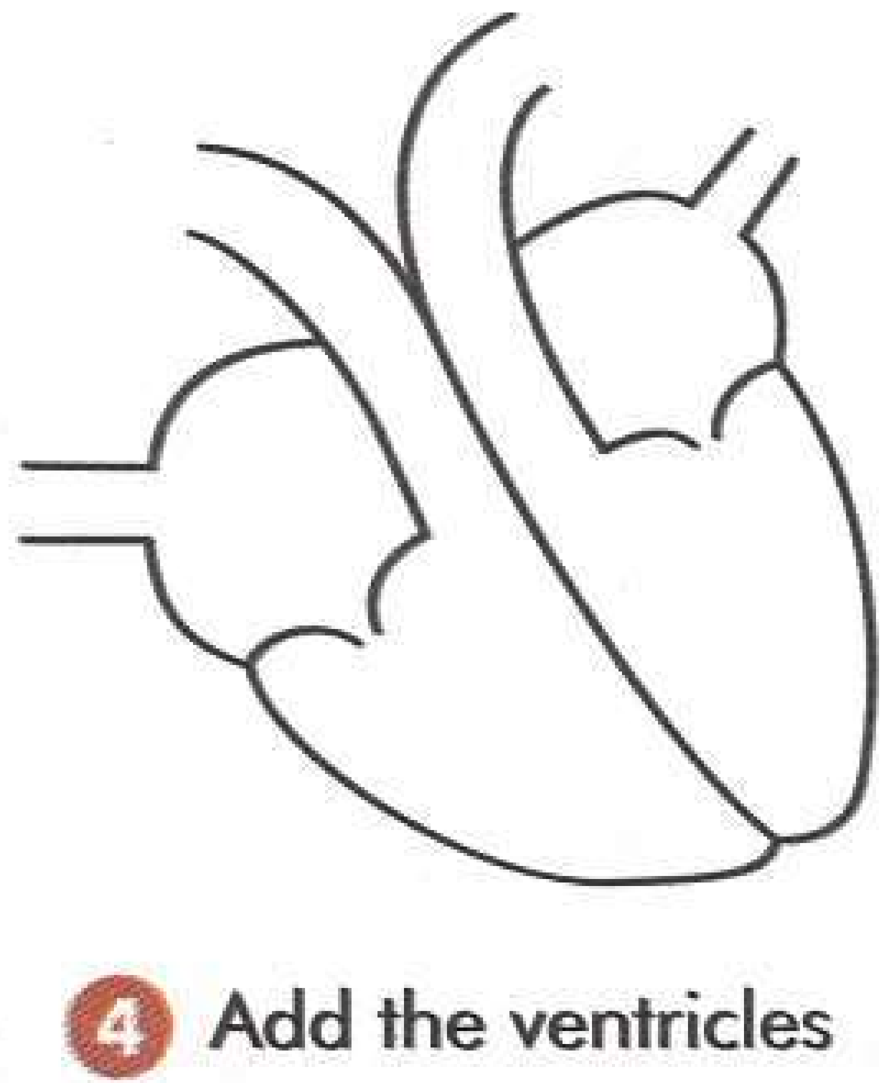
1 Draw a line across your page like this

How to draw the heart (2/6)

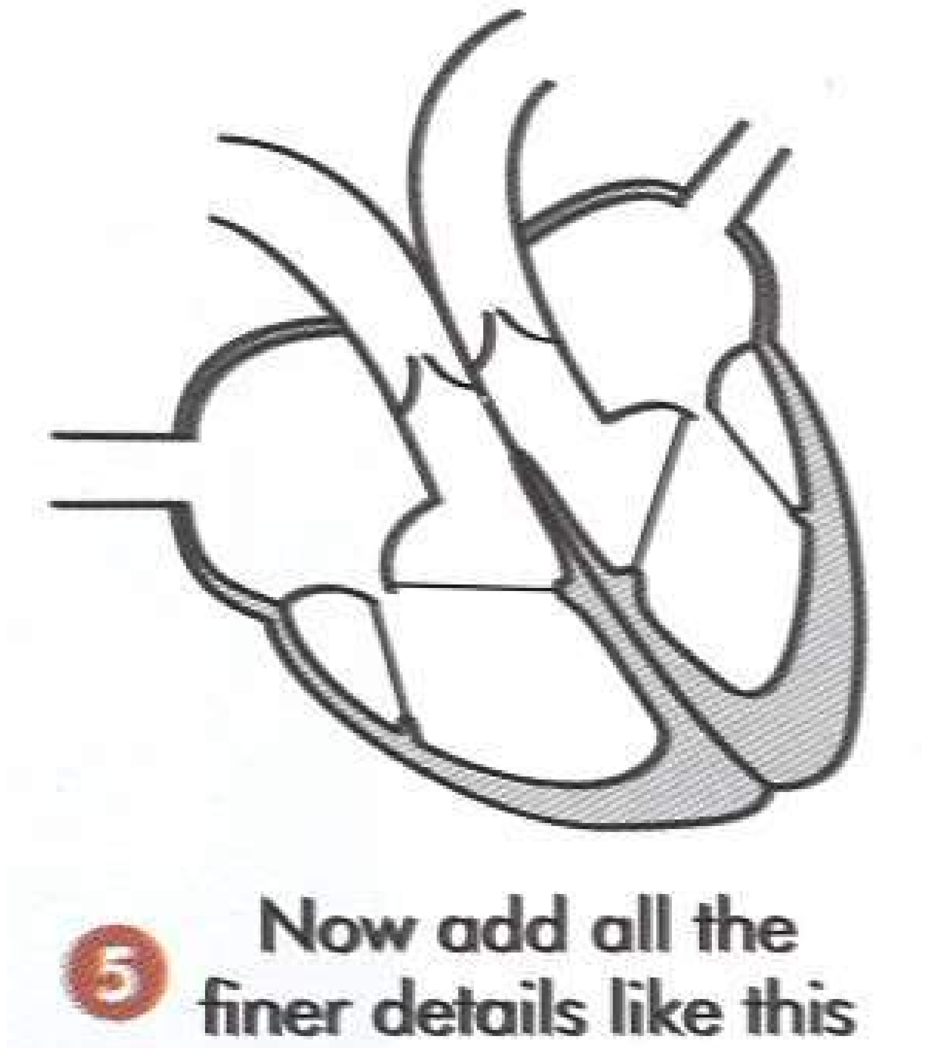
2 Add arteries and valves like this

How to draw the heart (3/6)

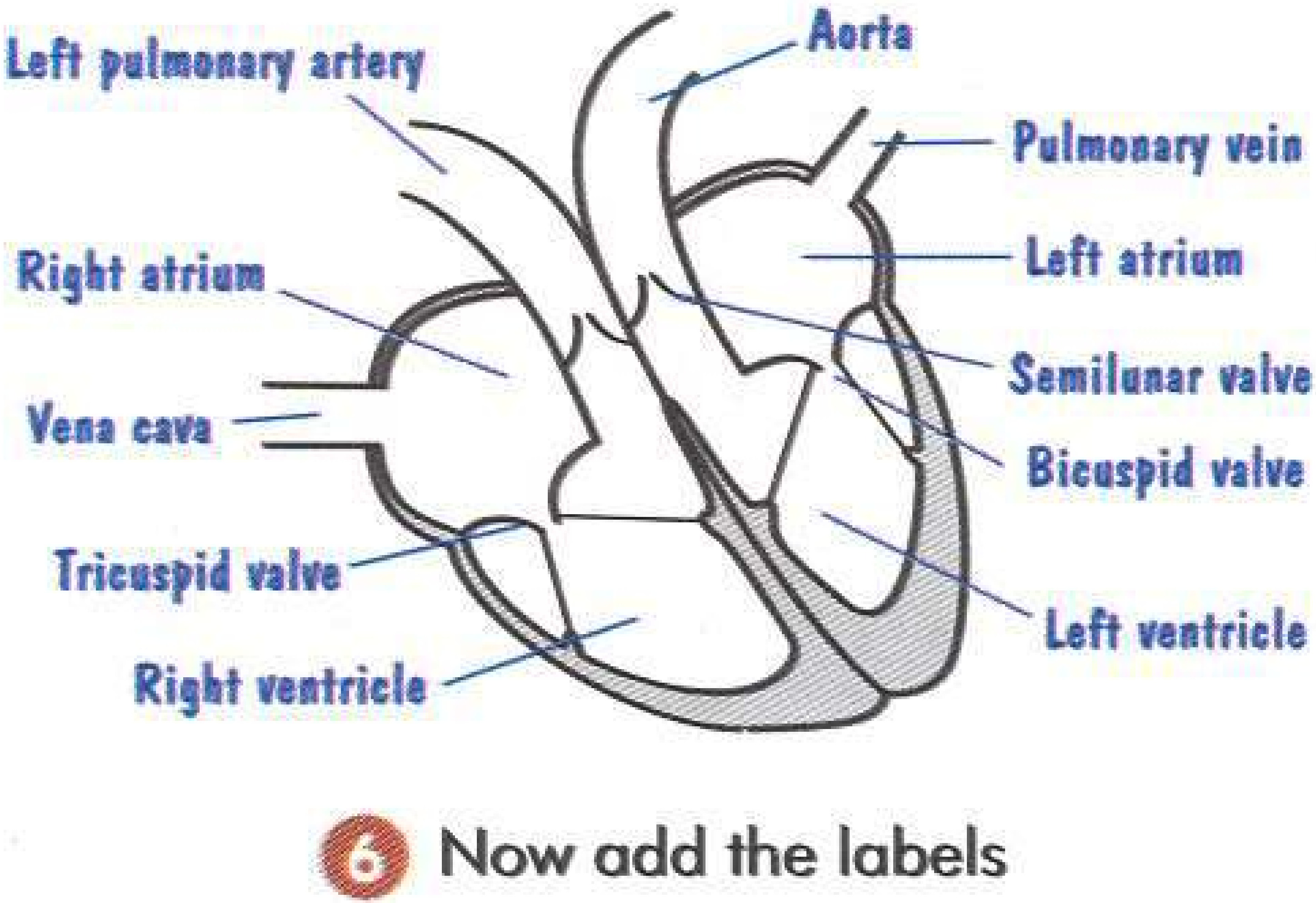
How to draw the heart (4/6)



How to draw the heart (5/6)



How to draw the heart (6/6)



Systole & Diastole

Systole: contraction phase of cardiac cycle during which the chambers discharge the blood.

Diastole: relaxation phase of cardiac cycle during which the chambers fill with blood.

Heartbeat (1/2)

Pacemaker (S-A node) located in right atrium sends out wave of impulses to muscles of *both atria* causing atria to contract.

This is Atrial systole.

The impulses are picked up by the atrio-ventricular node (A-V node)

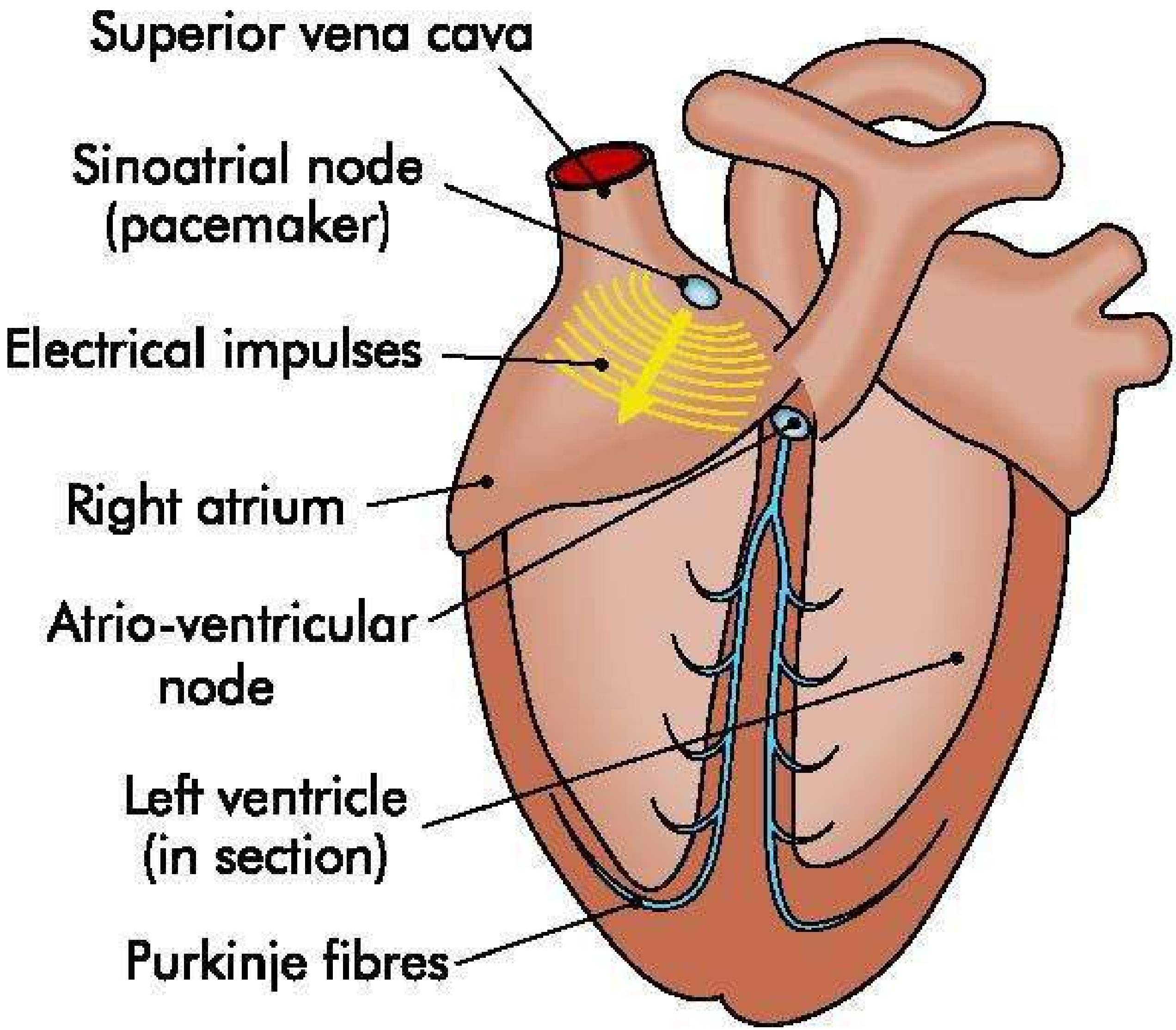
Heartbeat (2/2)

and transmitted to the ventricles via the Purkinje fibres - causing the ventricles to contract.

This is Ventricular systole.

While the atria are contracting and emptying (atrial systole) the ventricles are relaxing and filling with blood (ventricular diastole) and vice versa

Heartbeat – diagram



Heartbeat sound

The lupp-dup sound, heard through a stethoscope, is caused by the closing of the valves of the heart

The Pulse

When the ventricles contract blood is forced through the aorta and into the arteries.

This causes the arterial walls to expand and contract rhythmically.

This is the pulse and can be felt where an artery is near the body surface e.g. wrist, temple, neck.

Blood Pressure

Is caused by the pumping action of the heart.

Needs to be reasonable high to keep the blood moving.

Highest pressure is where the blood is forced into the aorta by contraction of the left ventricle = systolic pressure

Lowest pressure is when the ventricles relax = diastolic pressure

Taking blood pressure

Use a B.P. machine = sphygmomanometer

Measures pressure required to stop the blood flow in artery of upper arm

Contraction and relaxation pressures recorded

Expressed as a fraction

Systolic pressure

Diastolic pressure

Blood pressure readings

e.g. healthy young adults B.P. = 120/80 mmHg

Hypertension = abnormally high blood pressure
i.e. > 140/90 mmHg

Hypotension = abnormally low blood pressure.

Healthy Circulatory System

Effects of

Exercise,

Diet and

Smoking

on the circulatory system

Exercise

- When we exercise the heart beats faster.

Makes the heart muscle stronger

- More efficient at pumping blood

- Improves the oxygen supply to the cardiac muscle and Reduces blood pressure

Diet

Too much cholesterol from animal fats can build up on the inner walls of the arteries

and reduces the rate of flow of the blood

e.g. a blockage in the cardiac artery prevents blood and oxygen getting to the cardiac muscle and will cause a heart attack

Eating fewer fatty meats and fatty dairy products can reduce the risk of heart disease

Smoking

Major cause of heart disease

Tobacco smoke contains nicotine and carbon monoxide (CO)

Nicotine increases blood pressure

CO interferes with the transport of oxygen to the body cells

High levels cause hardening of the arteries

Lecture 5 of biophysics

PHYSICS OF EYES AND VISION

The sense of vision consists of three major components:

- The eyes that focus an image from outside world on the light sensitive retina.
- The system of millions of nerves that carries the information deep into the brain.
- The visual cortex-that part of the brain where, it is all put together.

Blindness results if any one of the parts does not function.

The physics of the first part far better than the physics of the other two parts.

Focusing Elements Of The Eye

The eye has two major focusing components:

- 1-The cornea is a fixed focus element.
- 2-The lens is variable in shape and has the ability to focus objects at various distances.

Focusing Elements Of The Eye

The cornea focuses by bending (refracting) the light rays. The amount of bending depends on the curvatures of its surfaces and the speed of light

- in the lens compared with that in the surrounding material. The index of refraction is nearly constant for all corneas, but the curvature varies considerably from one person to another and is responsible for most our defective vision.

Focusing Elements Of The Eye

- 1- If the cornea is curved too much the eye is near sighted.
- 2- Not enough curvature results in far sightness.
- 3 -Uneven curvature produces astigmatism.

Focusing Elements Of The Eye

- The lens has a flexible cover that is supported under tension by suspension fibers.
- When the focusing muscle of the eye is relaxed this tension keeps the lens somewhat flattened and adjusted to its lowest power, and the eye is focused on distant objects. The point at which distant objects are focused when the focusing muscle is relaxed is called the far point.
-

Focusing Elements Of The Eye

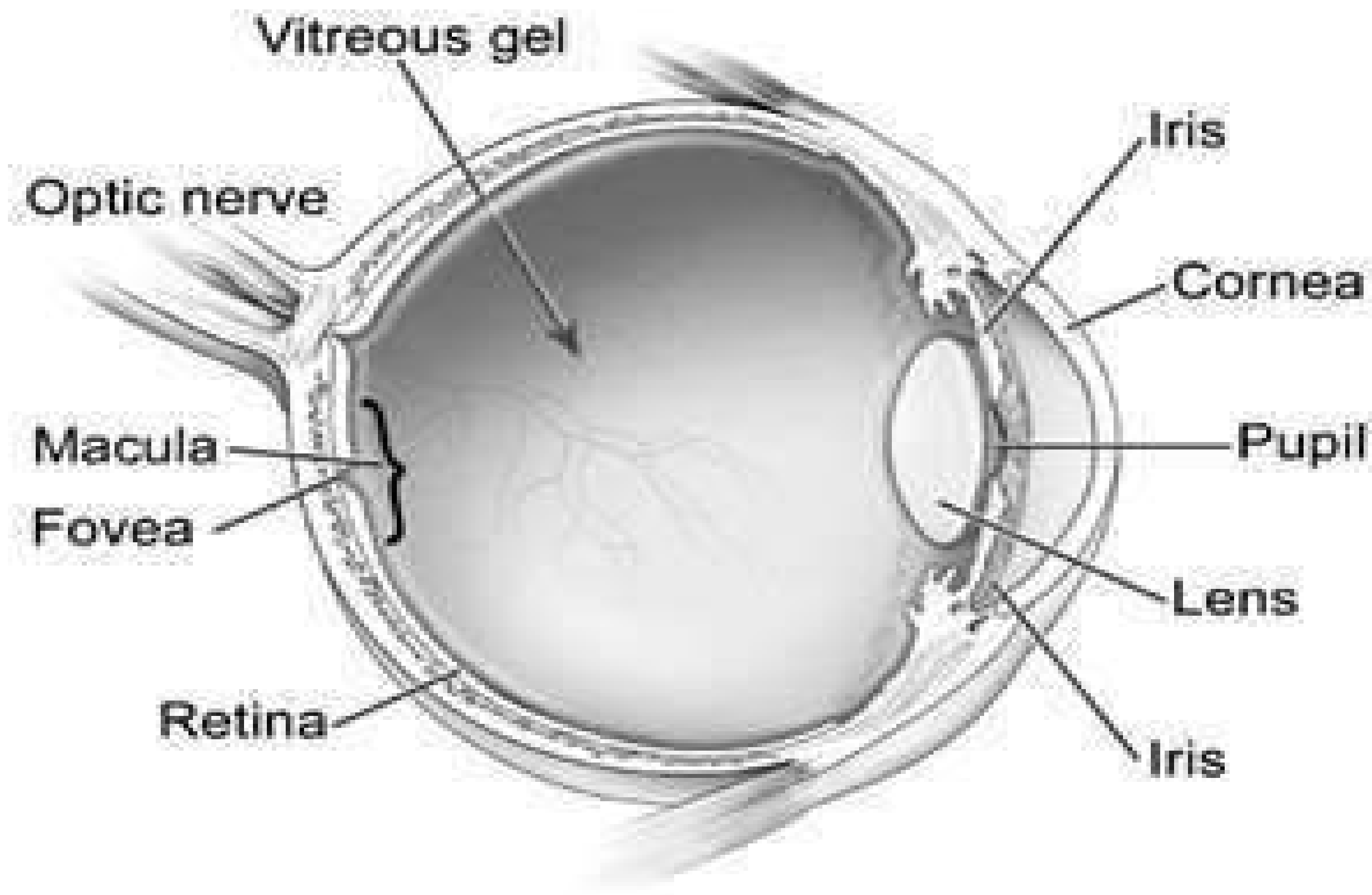
For a near sighted, the circular muscle around the lens contracts into a smaller circle and takes some or all of the tension off the lens. The lens then has a greater focusing power, the closest point at which objects can be focused when the lens is its thickest is called the near point.

Focusing Elements Of The Eye

- Young children have very flexible lenses and can focus on very close objects. the ability to change the focal power of the eye is called accommodation.

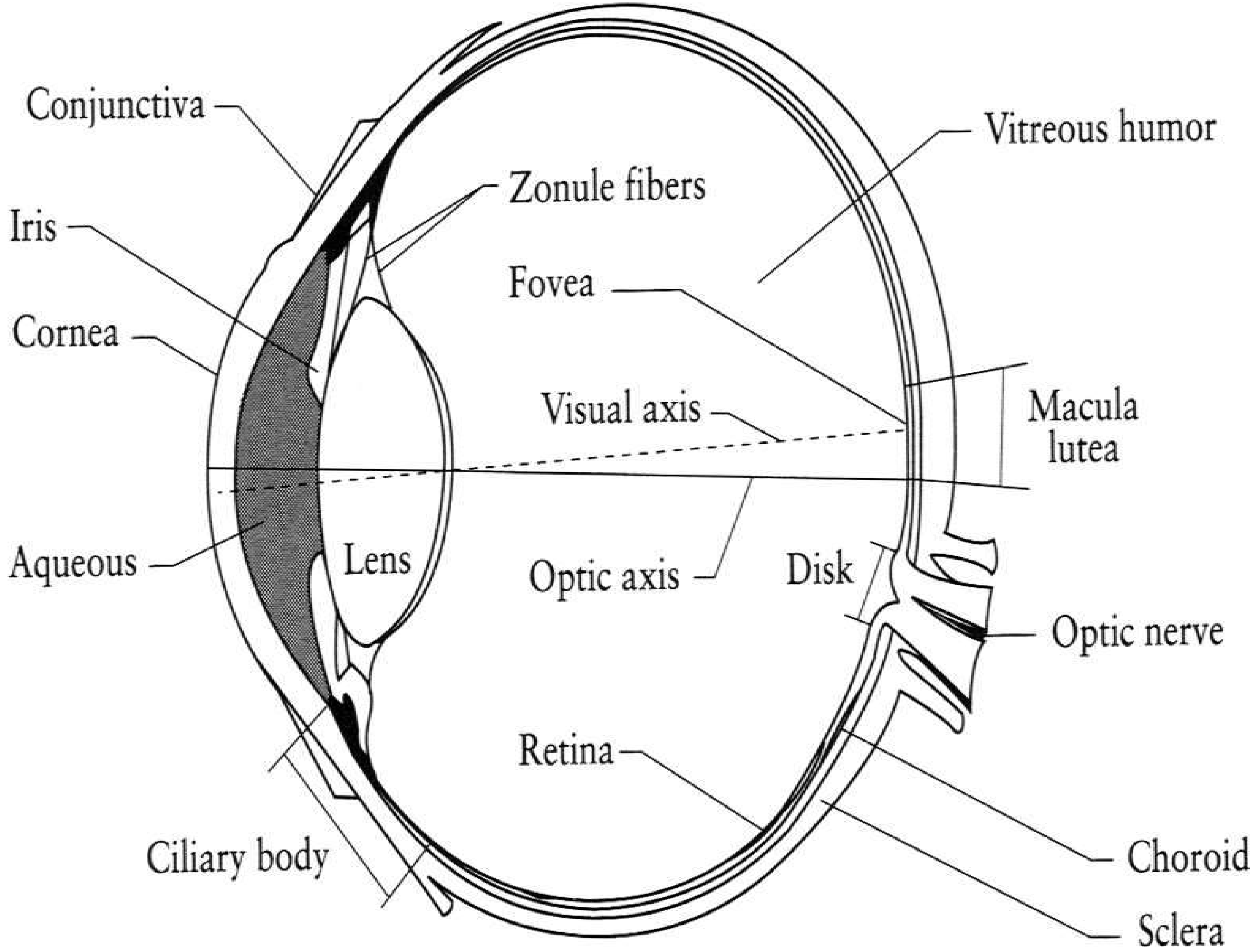
- As people get older, their lenses lose some accommodation, presbyopia
- (old sight) results when the lens has lost nearly all of its accommodation.

Some Other Elements Of The Eye



Some Other Elements Of The Eye

- Pupil is the opining in the center of the iris where light enters the lens.
- It appears black because essentially all of the light that enters is absorbed inside the eye. Under average light condition, the opining is about 4mm in diameter.
- It can change from about 3mm in diameter in bright light to about 8mm in diameter in dim light. The iris does not respond instantly to a change of light levels; about 300 s are needed for it fully open, and about 5 s are required for it to close as much as possible.
-


Conjunctiva
Iris
Cornea
Aqueous
Ciliary body
Zonule fibers
Fovea
Visual axis
Lens
Optic axis
Retina
Vitreous humor
Macula
lutea
Disk
Optic nerve
Choroid
Sclera

Some Other Elements Of The Eye

- Aqueous humor fills the space between the lens and the cornea. This fluid, mostly water, is continuously being produced, and the surplus escapes through a drain tube.

- Vitreous humor is a clear jelly that fills the large space between the lens and the retina. It helps keep the shape of the eye fixed and essentially permanent.

- Sclera is the tough, white, light-tight covering over all of the eye except the cornea.

The Retina-The Light Detector Of The Eye

- The retina, the light sensitive part of the eye, converts the light images into electrical nerve impulses that are sent to the brain. The absorption of a light photon in photoreceptor triggers an electrical signal to brain-an action potential. The light photon apparently cause a photochemical reaction in the photoreceptor which in some way initiates the action potential. The photon must be above a minimum energy to cause the reaction.

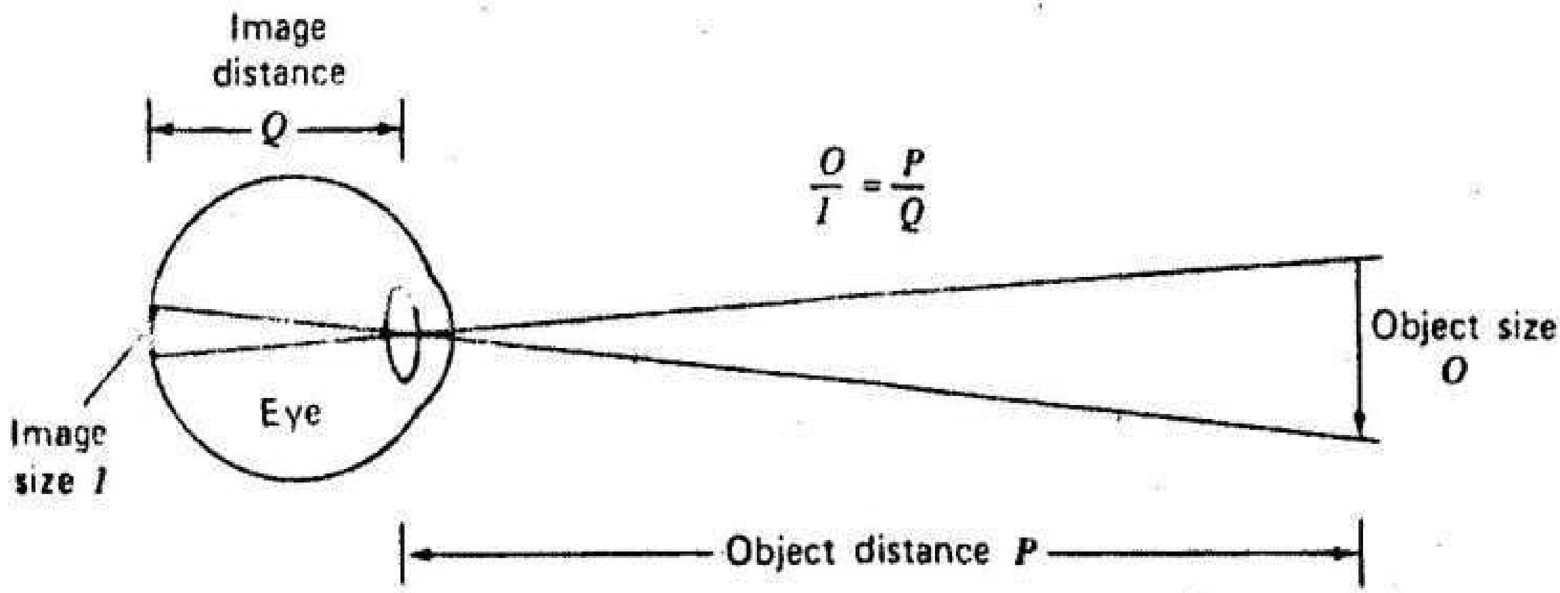
The Retina-The Light Detector Of The Eye

- Infrared photons have insufficient energy and thus are not seen.
- Ultraviolet photons have sufficient energy, but absorbed before they reach the retina and also are not seen.

- The retina covers the black half of the eyeball.While this large expanse permits useful" warning" vision over a large angle, most vision is restricted to a small area called the macula lutea, or yellow spot. All detailed vision takes place in a very small area in the yellow spot (~0.3mm in diameter) called the fovea centralis.

The Retina-The Light Detector Of The Eye

- The image on the retina is very small. A convenient equation for determining the size of image on the retina comes from the ratios of the lengths of the sides of similar triangles.



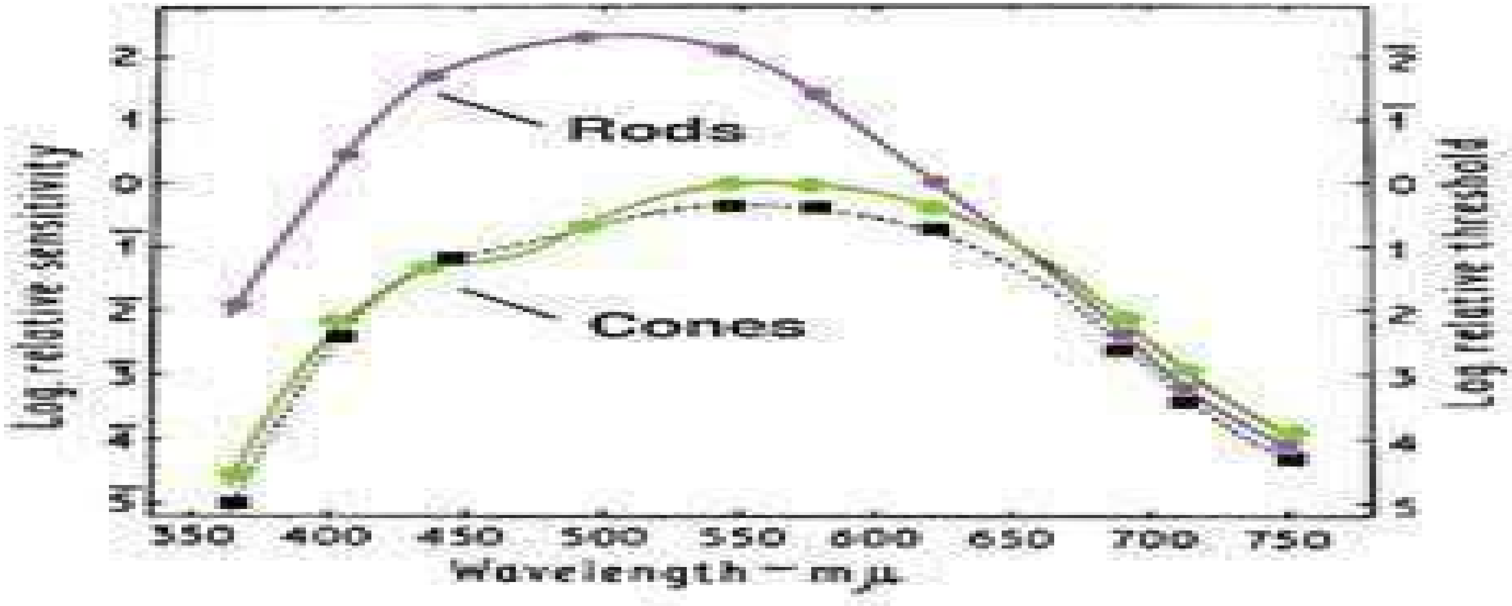
- I: is image size Q: is image distance
- O: is object size P: is object distance
- Thus we can write O/P=I/Q

The Retina-The Light Detector Of The Eye

- There are two general types of photoreceptors in the retina: the cones and the rods, the rods and cones are distributed symmetrically in all directions from visual axis except in one region-blind spot .
-
- Throughout most of the retina the cones and rods are not at the surface of the retina but the lie behind several layers of the nerve tissue through which the light must passes.

The Retina-The Light Detector Of The Eye

- The cones are used for daylight, or photopic, vision. With we can see fine detail and recognize different colors. The cones are found in the fovea centralis. Each of the cones in the fovea has its own telephone line to the brain. The cones are not uniformly sensitive to all colors but have a maximum sensitivity at about 550 nm in the yellow – green region.



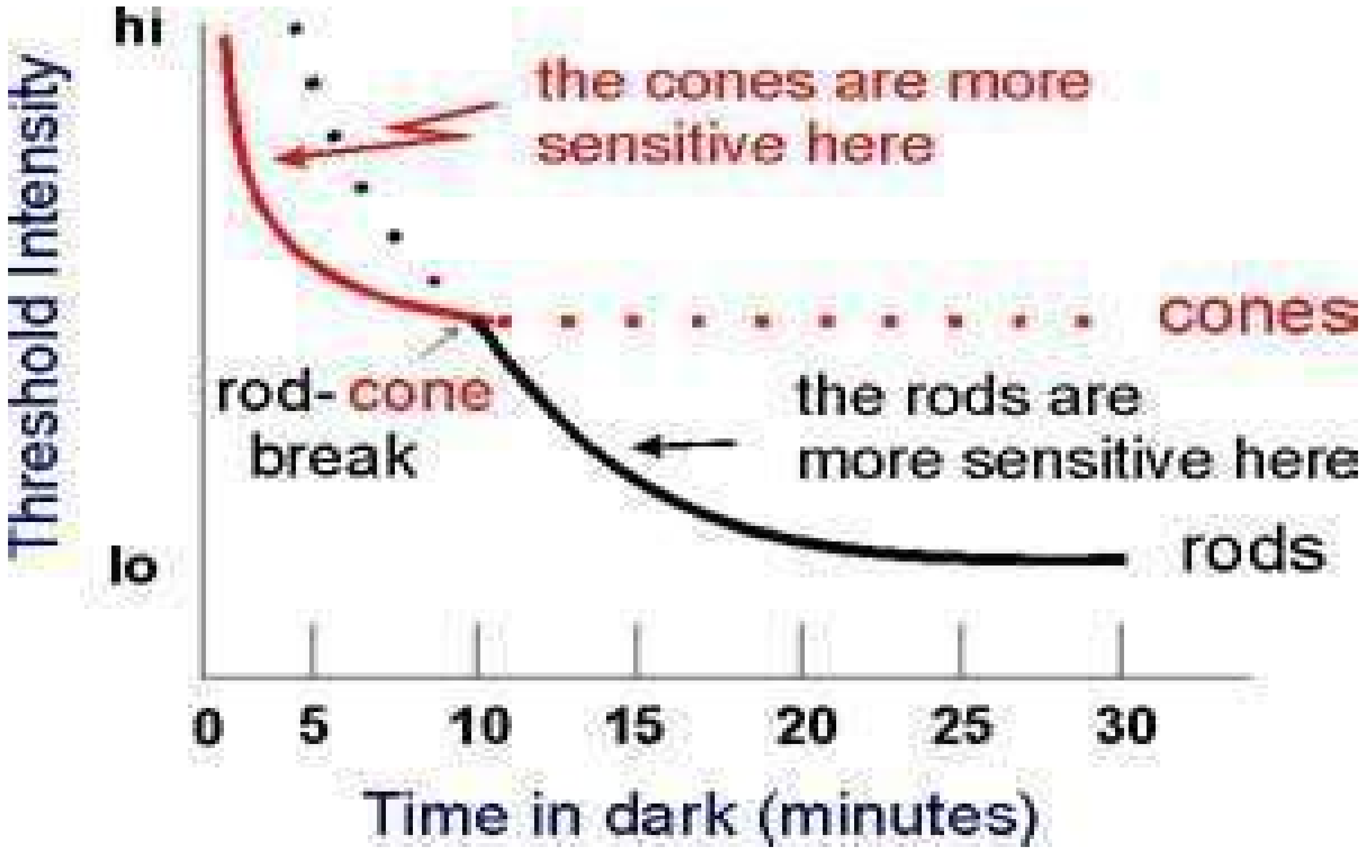
- The rods are used for night, or scotopic, vision and for peripheral vision. they are not uniformly distributed over the retina but have a maximum density at an angle of about 20°.

The Retina-The Light Detector Of The Eye

- That is, if you are looking at the sky at night, the light from a faint star displaced 20o from your line vision will fall on the most sensitive area of your retina. If you look directly toward the faint star, its image will fall on your fovea which has no rods and you will not see it.
- The rods are most sensitive to blue green (510 nm) .The rods and cones are equally sensitive to red light (650 to 700nm).

Dark adaptation

- is apparently the time needed for the body to increase the
- supply of photosensitive chemicals to the rods and cones.
- The eyes do not have their greatest sensitivity to light under photopic conditions, if the light level suddenly decreases by a factor of 1000 we are momentarily "in dark", but after a few minutes we are able to see many of details that were not visible when it first became dark.
- The cones adapt most rapidly; after about 5 min the fovea centralis has reached its best sensitivity. The rods continue to dark adapt for 30 to 60min, although most of their adaptation occurs in the first 15 min.

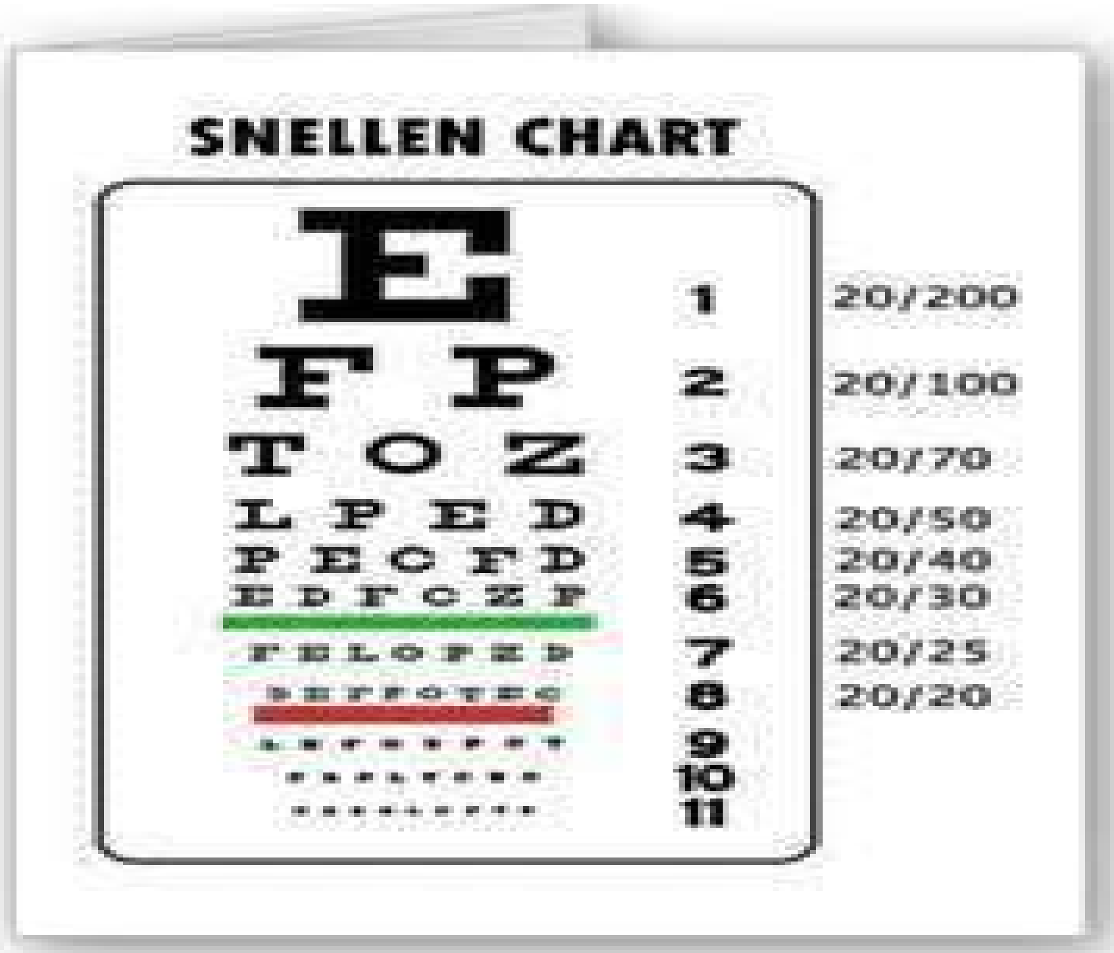


Blind spot: that has neither rods nor cones. that there is a region from about13° to 18°

How Sharp Are Your Eyes

- The optometrist usually uses a snellen chart to test visual acuity. If he tells you that your eyes test normal at 20/20, he means that you can read detail from 20 ft that person with good vision can read from 20 ft. If your eyes test at 20/40, you can just read from 20 ft the line that a person with good vision can read from 40 ft.

How Sharp Are Your Eyes



How Sharp Are Your Eyes

- The ability of the eye to recognize separate lines also depends on the relative "blackness "and "whiteness" , the contrast between two areas is defined as optical density OD
- OD = Log (Io/I)
- Where Io is the light intensity without absorber and I is intensity with absorber.
-

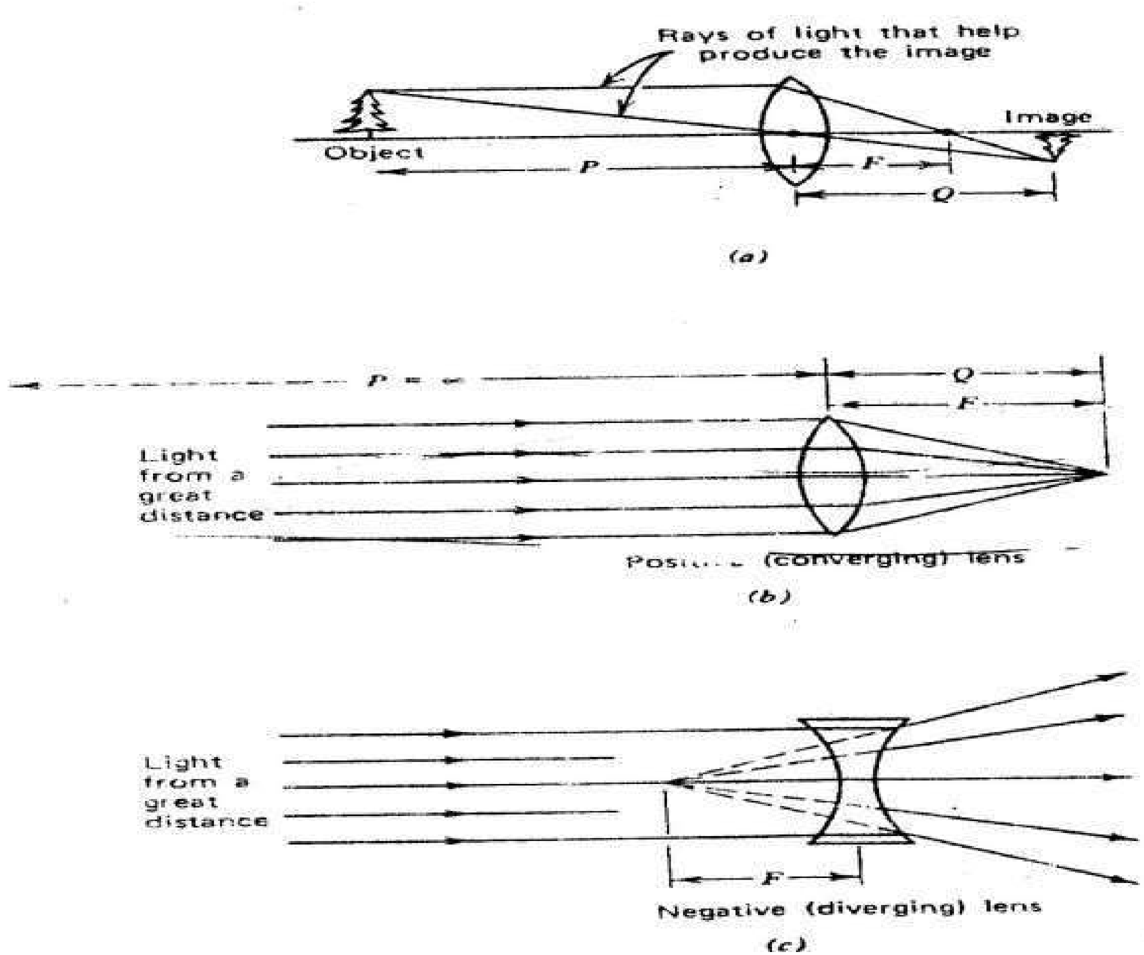
EXAMPLES

- EXAMPLE: A piece of film that transmits 10% of the incident light has an optical density
- OD = Log(1/0.1) = 1.0
- EXAMPLE: A film that absorbs 99% of the light has an optical density
- OD = Log(1/0.01) = 2.0
- An OD=3 means that only 0.001 of the light transmitted.
-

Defective Vision And Its Correction

- There is a simple relationship between the focal length F, the object distance P, and the image distance Q of the lens
- $1/F = 1/P + 1/Q$
- If F is measured in meters, then 1/F is the lens strength in diopters (D).

Defective Vision And Its Correction



- The ability of the eye to focus on objects over a wide range is called accommodation.
- Power of accommodation of normal eye =1/F
-
- 1/near point - 1/far point
- 1/0.25m – 1/∞

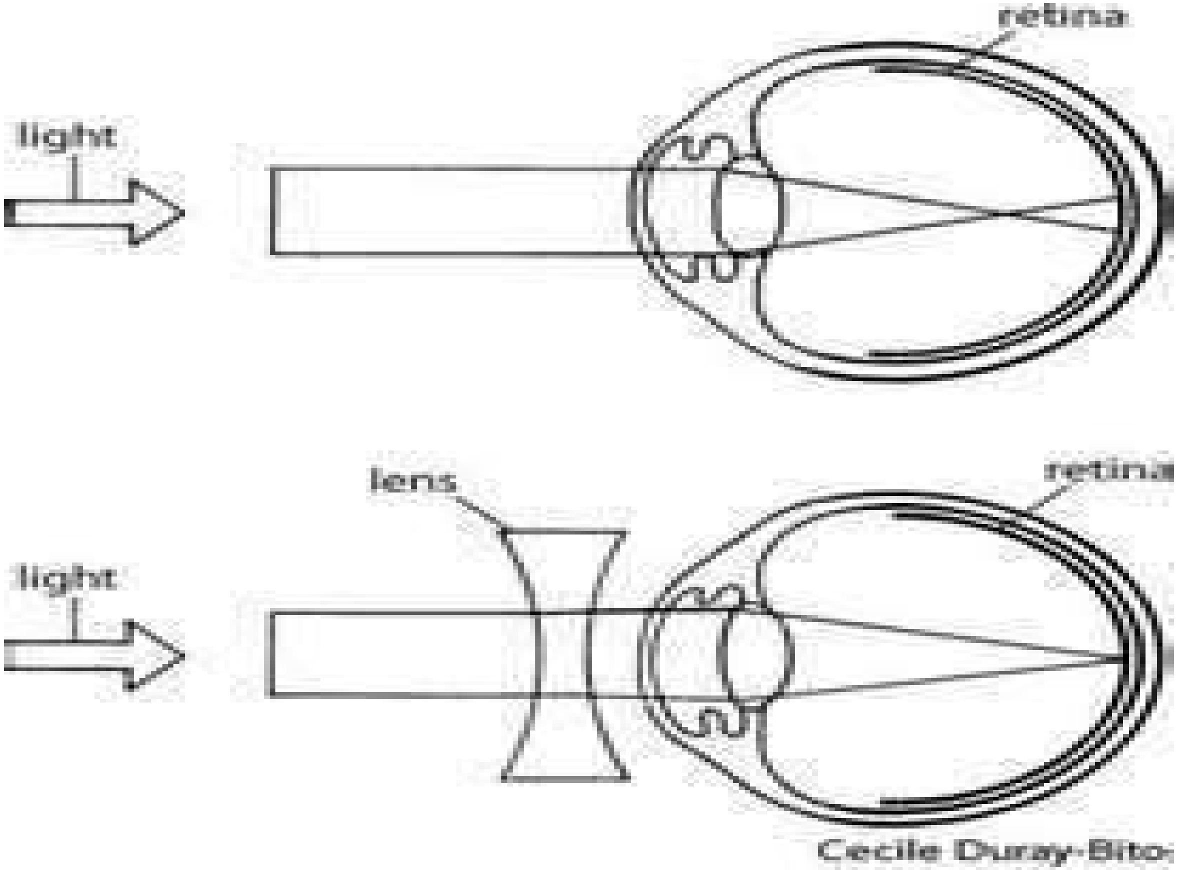
= 4 Diopter

MYOPIA

- The eyeball is too long, and parallel rays are focused by the relaxed eye to a position in front of the retina. Only near objects can therefore be seen clearly.

- This defect can be corrected by diverging lenses. If the spectacle lens is chosen to have a focal length equal in magnitude to the distance to the far point (F), then parallel rays striking the spectacles appear to the eye to diverge from the far-point. Note that the least distance of distinct vision for the spectacled eye is no longer d but increased to x.

MYOPIA

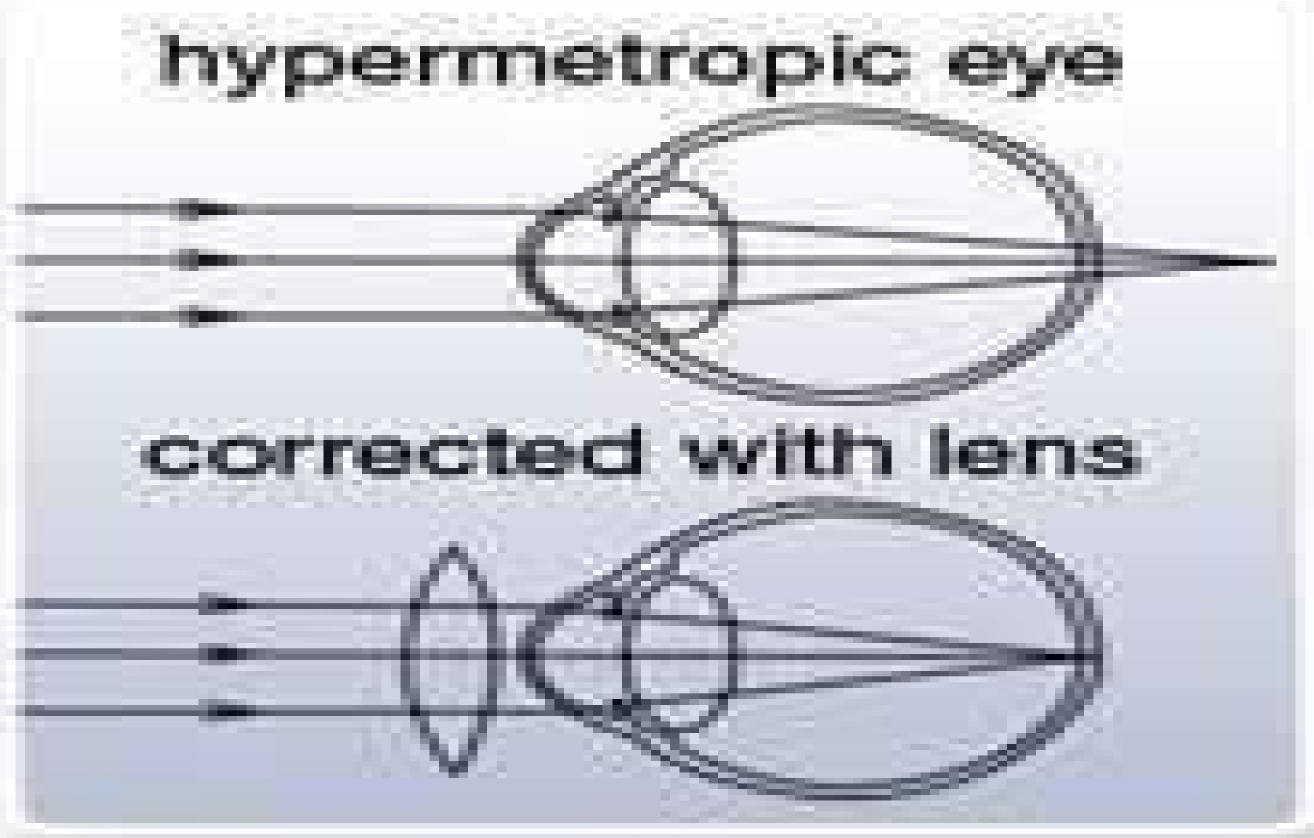


- **$-1/F = 1/x - 1/d$**
- An object at distance x must produce a virtual image at d in the spectacle lens
- in order just to be brought to focus by the eye.

HYPERMETROPIA

- This is the opposite effect. The eyeball is too short and parallel rays are focused to a point behind the retina, this defect is corrected by using converging spectacle lenses, if the near point is at d1. Then an object at d requires the lens to produce a virtual image of it at d1 which will then be visible to the fully accommodation eye in the other words the focal length of the spectacle lenses must be F.
- $1/F = 1/d - 1/d^1$

HYPERMETROPIA



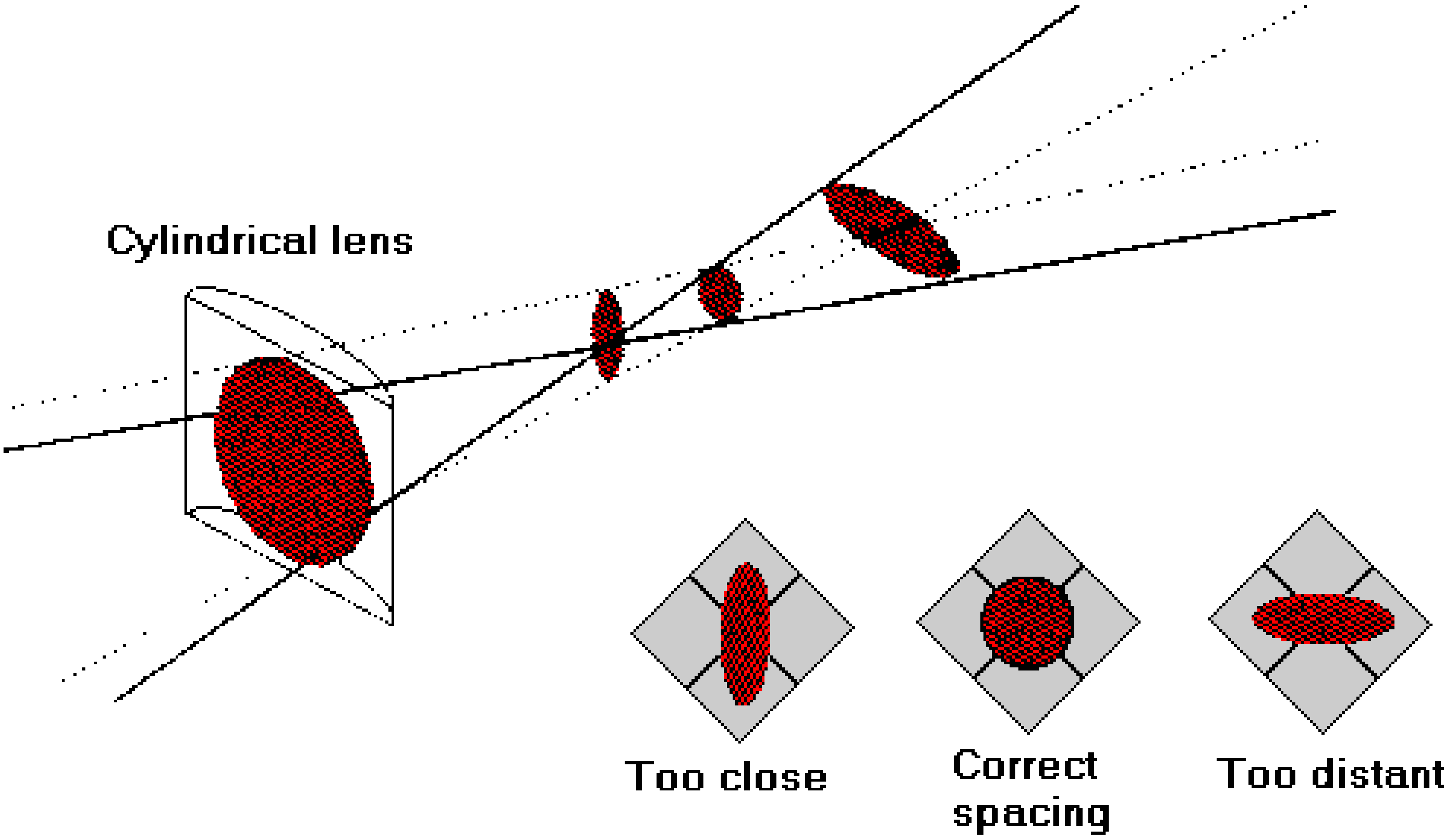
PRESBYOPIA

- As people get older the cillary muscles weaken and lens losses some of its elasticity . The power of accommodation diminishes with age. This defect is corrected by two parts of lenses upper half of each lens is diverging and corrects the myopia when the wears is looking ahead at distance objects, the lower half corrects the presbyopia with a suitable converging lens, and the wearer looks through this part when reading

ASTIGATISM

- When astigmatism is present, point objects do not form point images on the retina. This is normally due to the corneas unequal curvature in different directions. If the curvature is greater in a horizontal section than in the vertical section, rays brought to a focus more quickly in the horizontal than in the vertical plane. The defect is corrected by the use of cylindrical spectacle lenses.
-

ASTIGATISM



ASTIGATISM

- EX 1: A man has a near point 50cm and far point infinity, what is his useful accommodating power.
- 1/near point - 1/far point
- $1/0.5 – 1/\infty$
- = 2 Diopter

ASTIGATISM

- EX 2: What spectacle lenses would be prescribed for the man of example 1.

- 1/F corrected = 1/n.p for normal eye – 1/n.p defected
- 1/F corrected= 1/0.25m -1/0.5m = 2 Diopter
- F =1/2 Diopter = 0.5m = 50cm

ASTIGATISM

- EX 3: A myopic male has near and far point of 20cm and 250 cm respectively. What spectacle lens is prescribed for his defect and where is his near point.
- 1/F corrected = 1/f.p for normal eye – 1/f.p defected
- 1/F corrected = 1/∞ – 1/2.5m = - 0.4 Diopter
- F = -2.5m the lens is diverging
- The near point when wearing the spectacles will be
- 1/F corrected = 1/n.p after wearing glass – 1/n.p without glass
-
- 1/-2.5m = 1/n.p after wearing glass – 1/0.2m
- 1/n.p after wearing glass =1/0.2m -1/2.5m
- =5 Diopter – 0.4 Diopter = 4.6 Diopter
- n.p after wearing glass =1/4.6 Diopter =0.217m = 21.7cm

Lecture 6 of biophysics

Cellular Transport

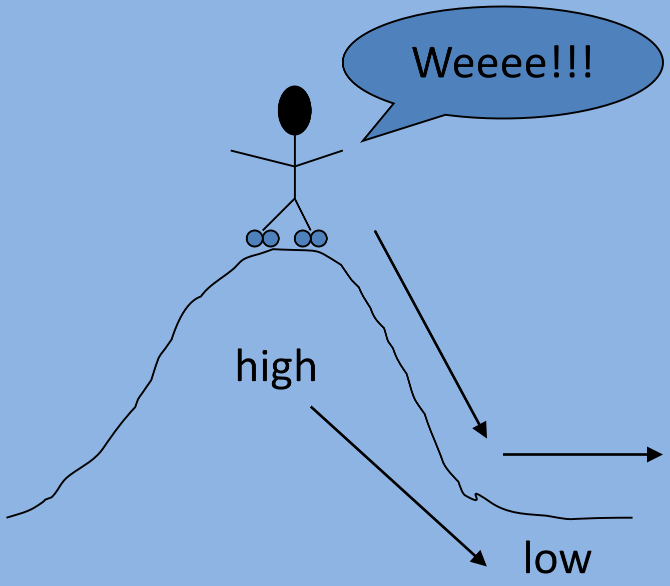
Types of Cellular Transport

•[Animations](#)of Active Transport & Passive Transport

- **Passive Transport**

  cell doesn't use energy

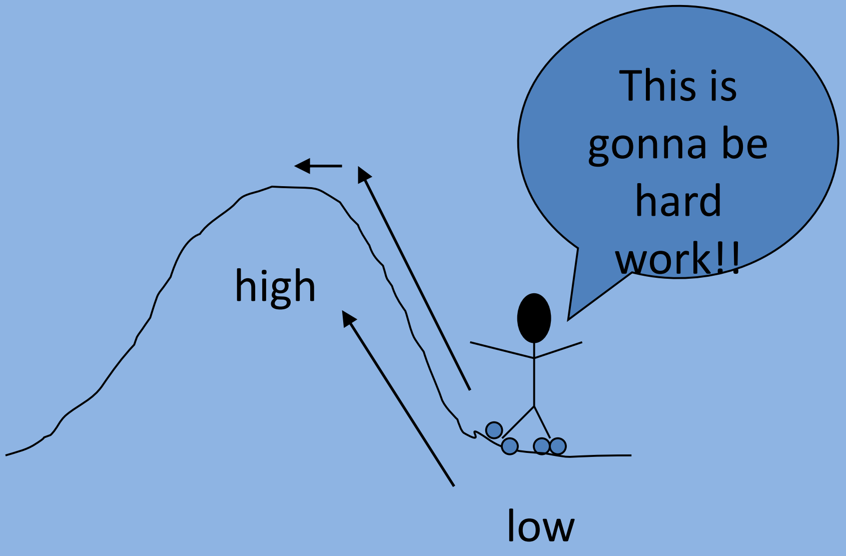
  1. Diffusion
  2. Facilitated Diffusion
  3. Osmosis



- **Active Transport**

  cell does use energy

  1. Protein Pumps
  2. Endocytosis
  3. Exocytosis



Passive Transport

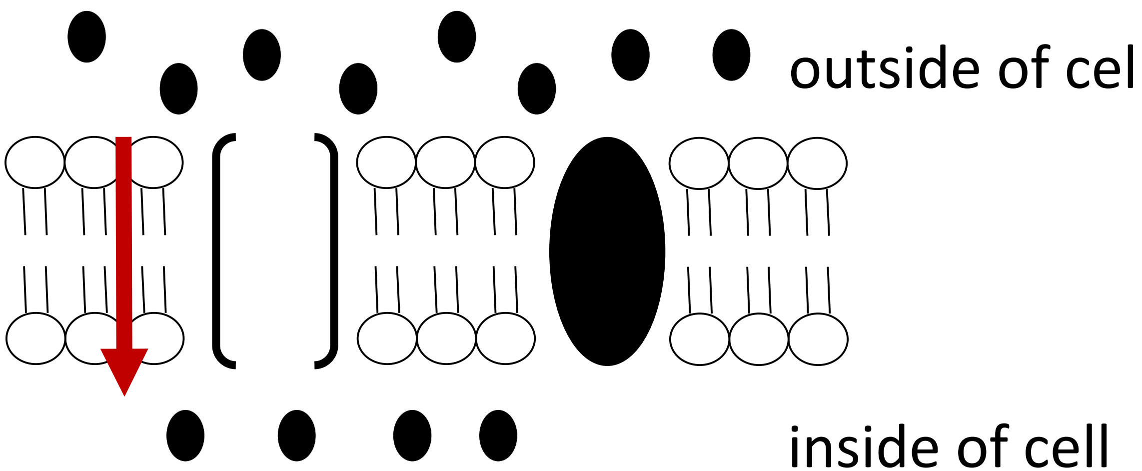
- Movement of materials **WITHOUT energy (ATP)**!
- Move from high concentration to low concentration
- Types of PASSIVE transport
  - Diffusion
  - Facilitated Diffusion
  - Osmosis

Passive Transport moves..

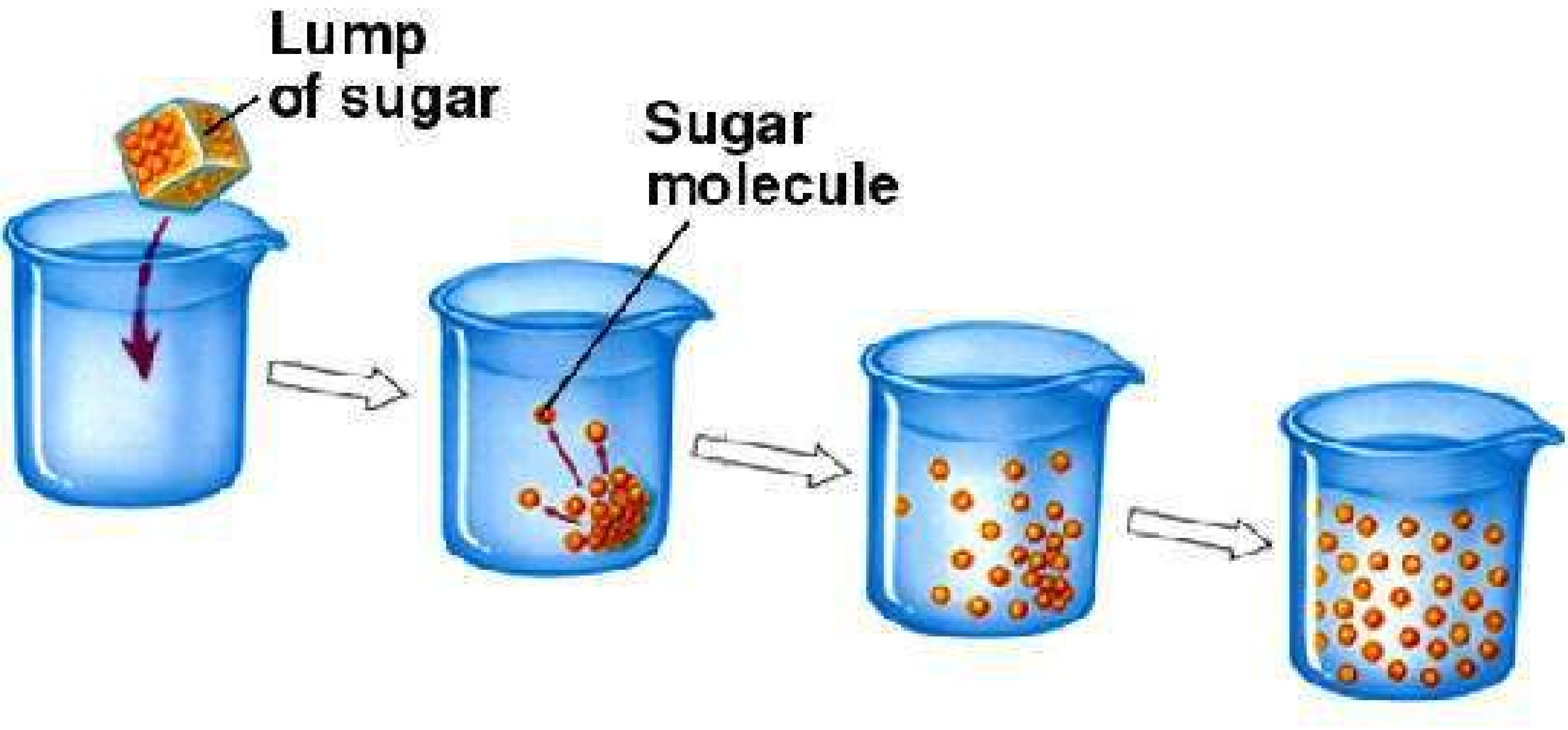
- Small molecules
- Uncharged molecules (do not have a + or -)
- Water
- Gases
  - Oxygen
  - Carbon Dioxide

- **<u>Diffusion</u>** is the movement of **<u>small</u>** particles across a **<u>selectively permeable</u>** membrane like the cell membrane until **<u>equilibrium</u>** is reached.

  These particles move from an area of **<u>high concentration</u>** to an area of **<u>low concentration</u>**.

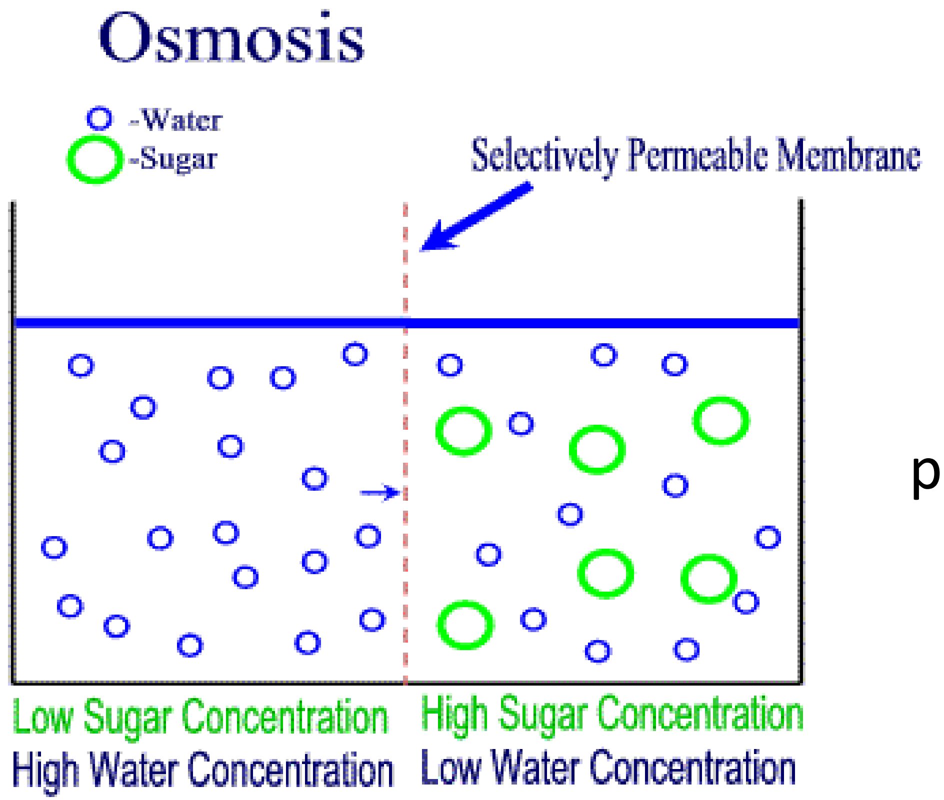


Diffusion



- **Osmosis** is the **diffusion** of **water** through a selectively permeable membrane like the cell membrane

  Water diffuses across a membrane from an area of **high concentration** to an area of **low concentration**.

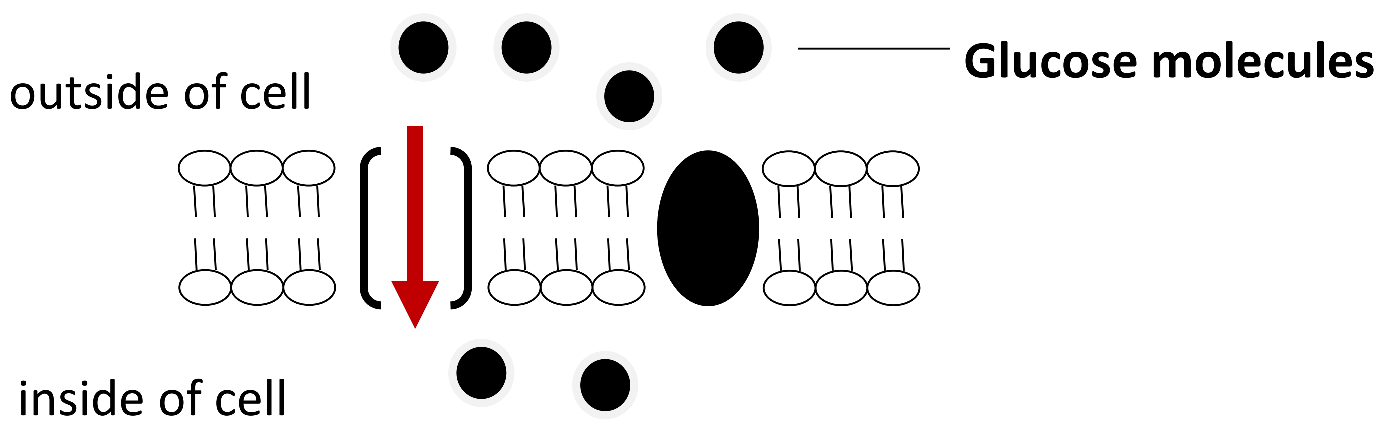


Semi-permeable membrane is permeable to water, but not to sugar

- **Facilitated Diffusion** is the movement of **larger molecules** like glucose through the cell membrane – larger molecules must be "helped"

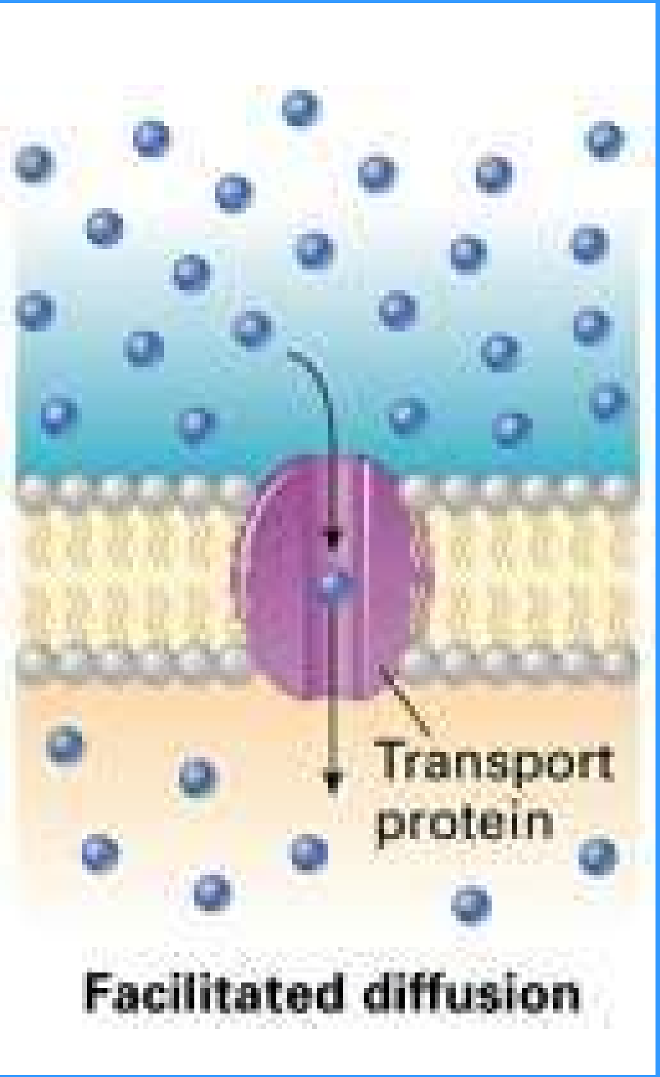
  Proteins in the cell membrane form **channels** for **large molecules** to pass through

  Proteins that form channels (pores) are called **protein channels**



Facilitated Diffusion

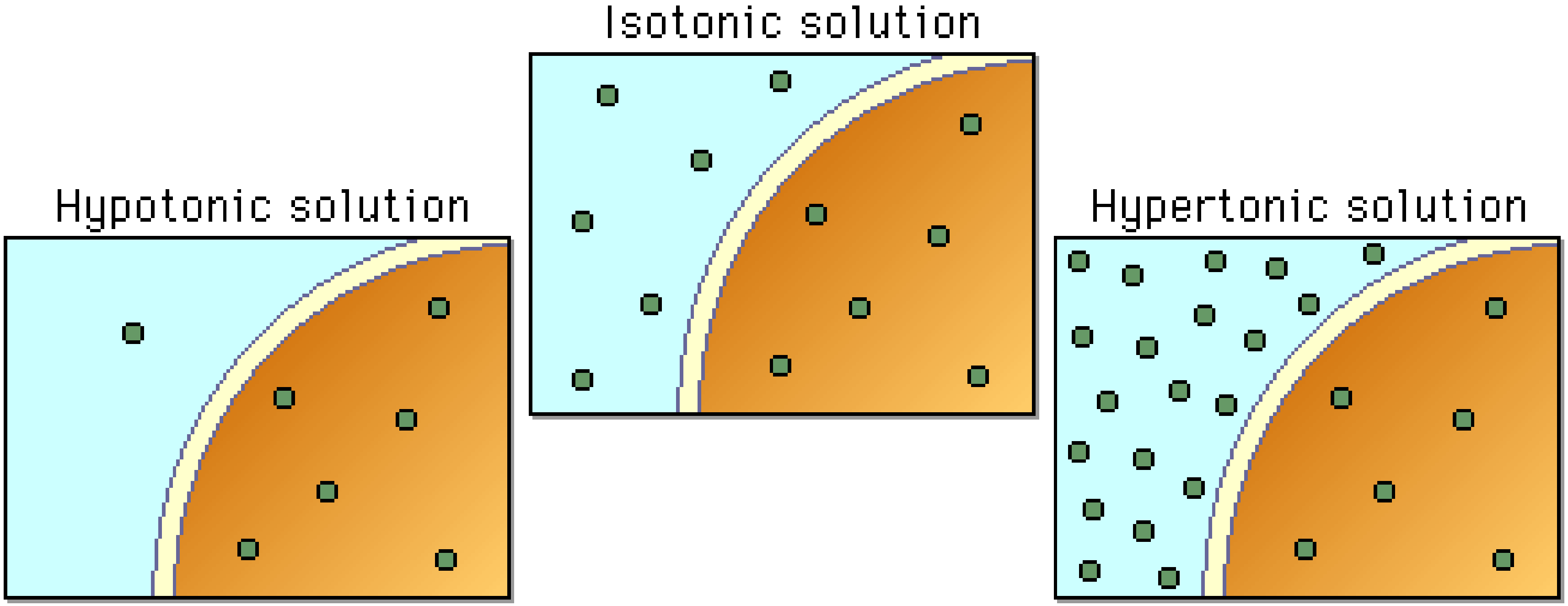
- Type of PASSIVE transport (no energy)
- *Diffusion* of a substance across the membrane with the help of a protein embedded in a membrane.
- **Movement is assisted**
  - Still moving molecules from high to low

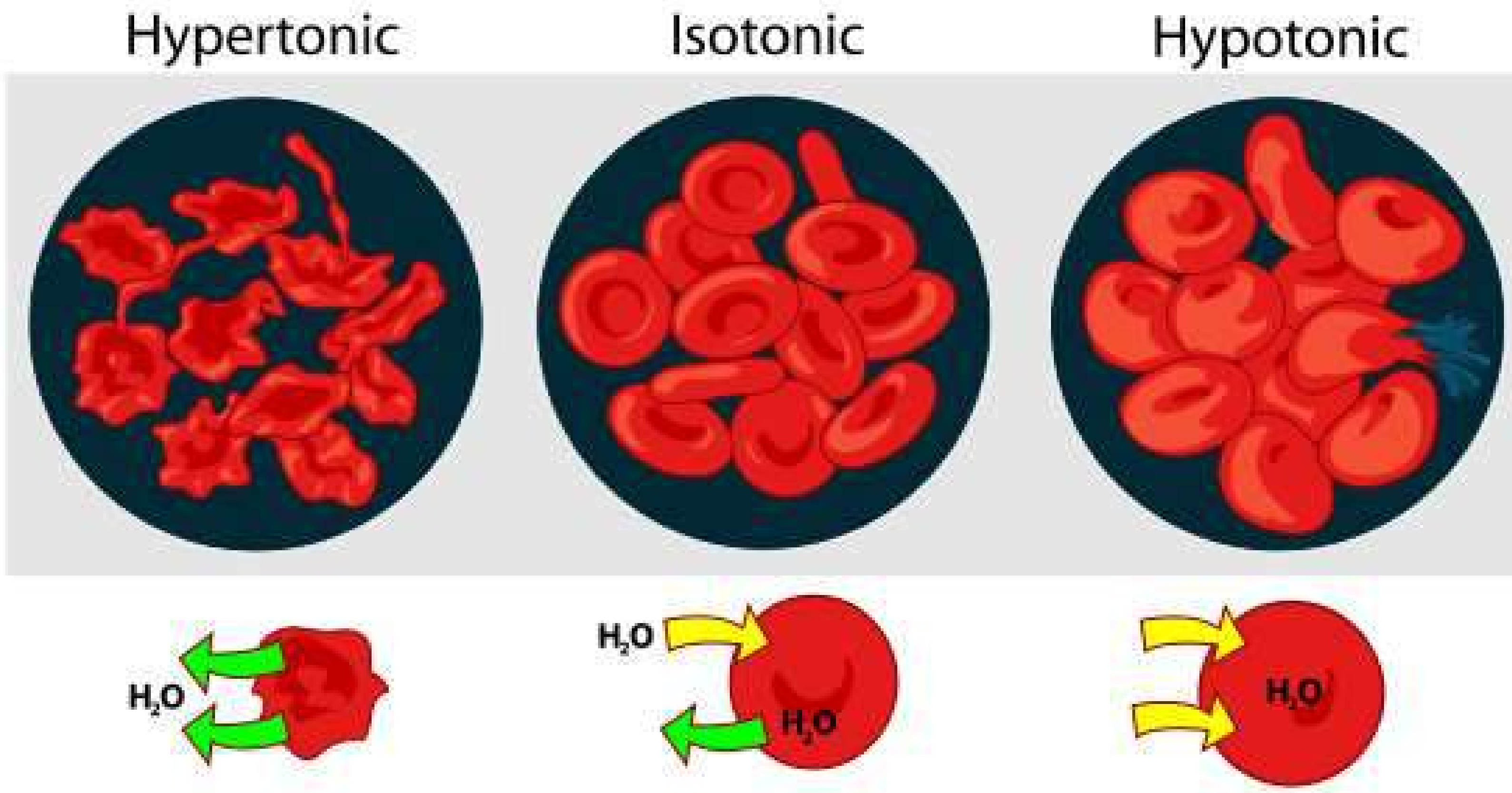


Hypertonic Solutions: contain a **high concentration** of solute relative to another solution .When a cell is placed in a hypertonic solution, the water diffuses **out** of the cell, causing the cell to **shrivel**.

Hypotonic Solutions: contain a **low concentration** of solute relative to another solution .When a cell is placed in a hypotonic solution, the water diffuses **into** the cell, causing the cell to **swell** and possibly **explode**.

Isotonic Solutions: contain the **same concentration** of solute as another solution .When a cell is placed in an isotonic solution, the water diffuses **into and out** of the cell at the same rate. The fluid that surrounds the body cells is isotonic.

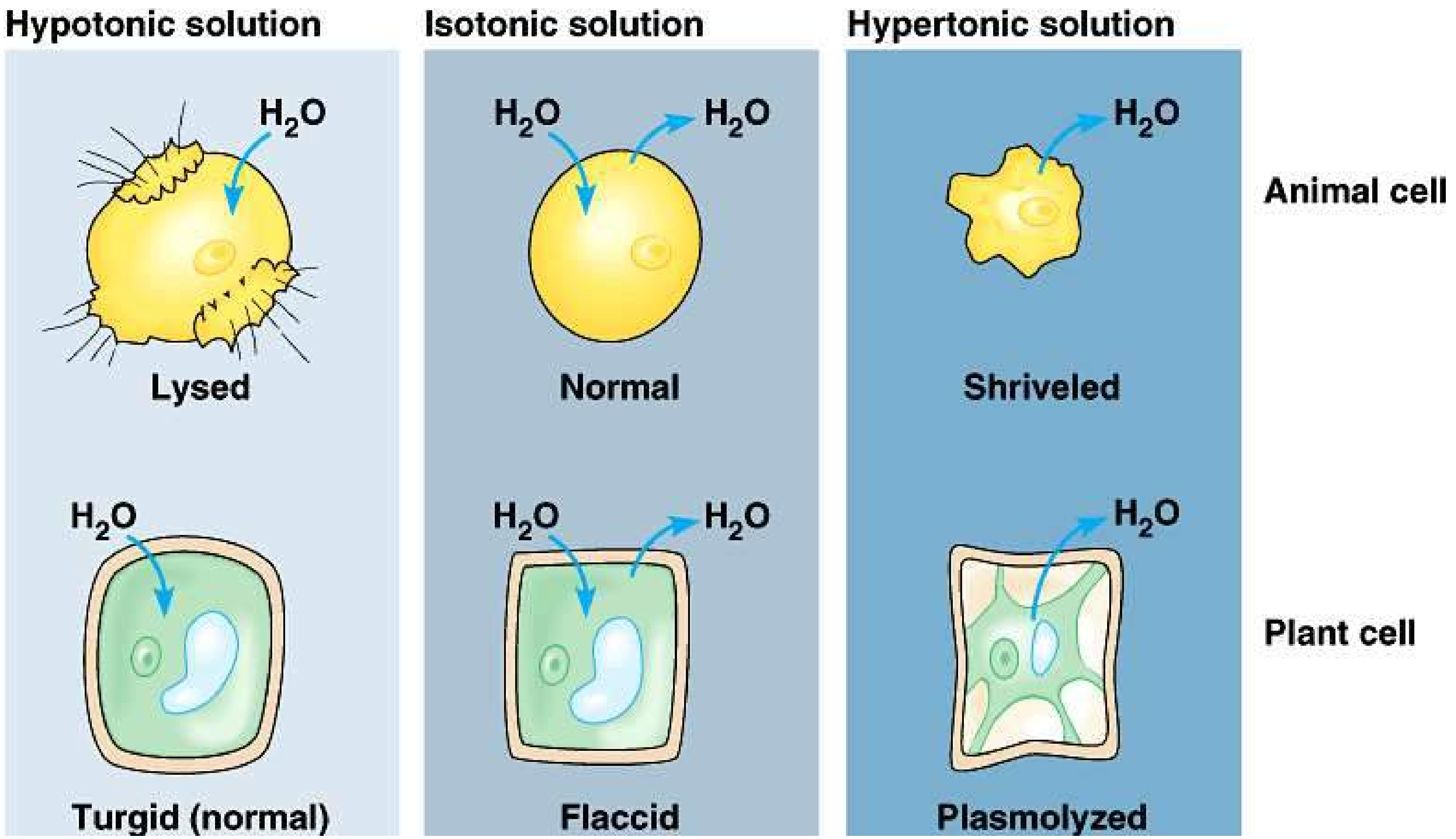

Isotonic solution
Hypotonic solution
Hypertonic solution



Interactive Red Blood Cell

Click

Hypo, Hyper, Isotonic…



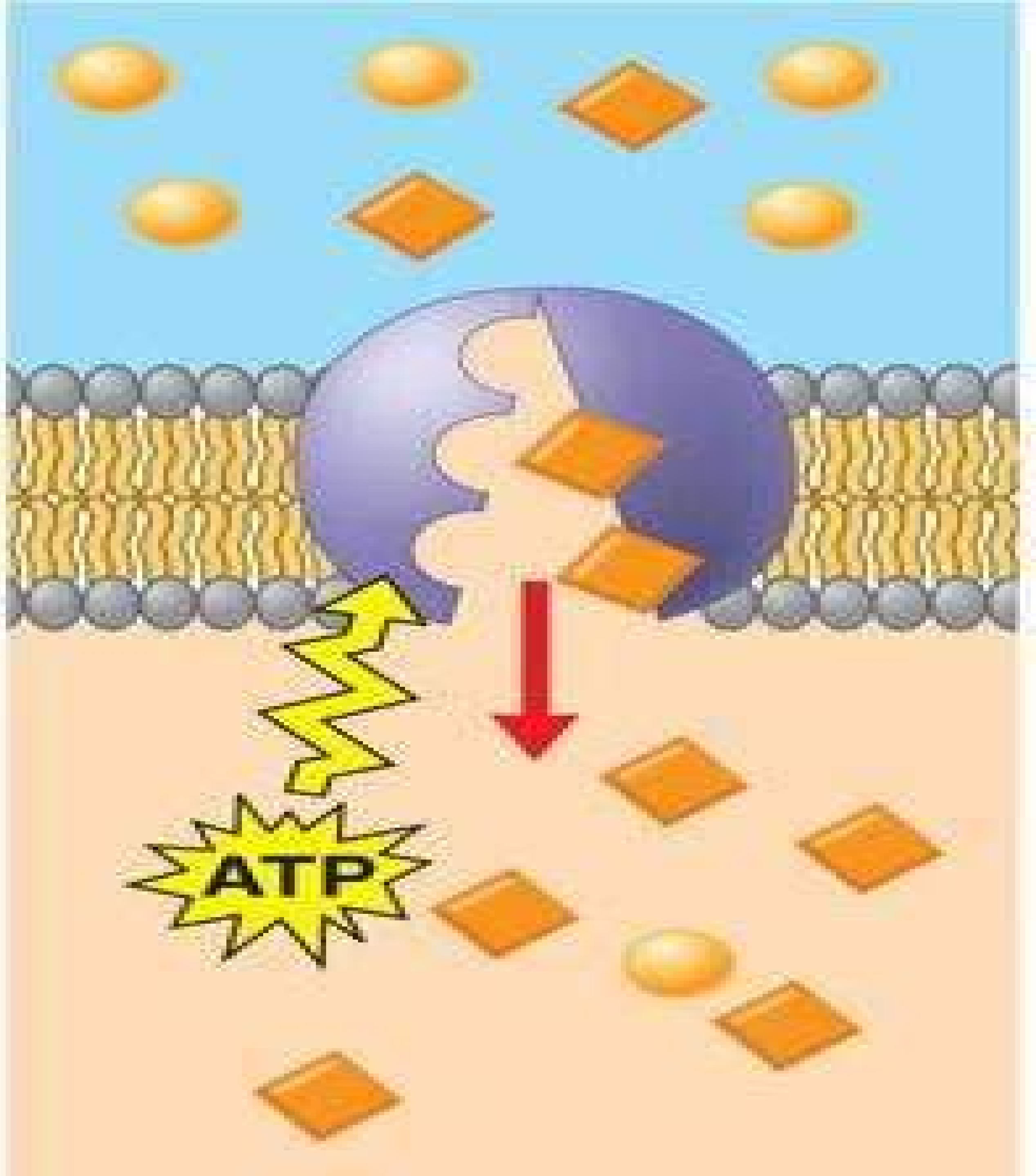
Active Transport

- REQUIRES ATP!!! (energy)
    - Takes work from cell's mitochondria
- Movement of molecules across the membrane against (up) the concentration gradient
- From LOW to HIGH concentration
- Types of Active
    - Pumps (proteins)
    - Endocytosis
    - Exocytosis

Active Transport moves…

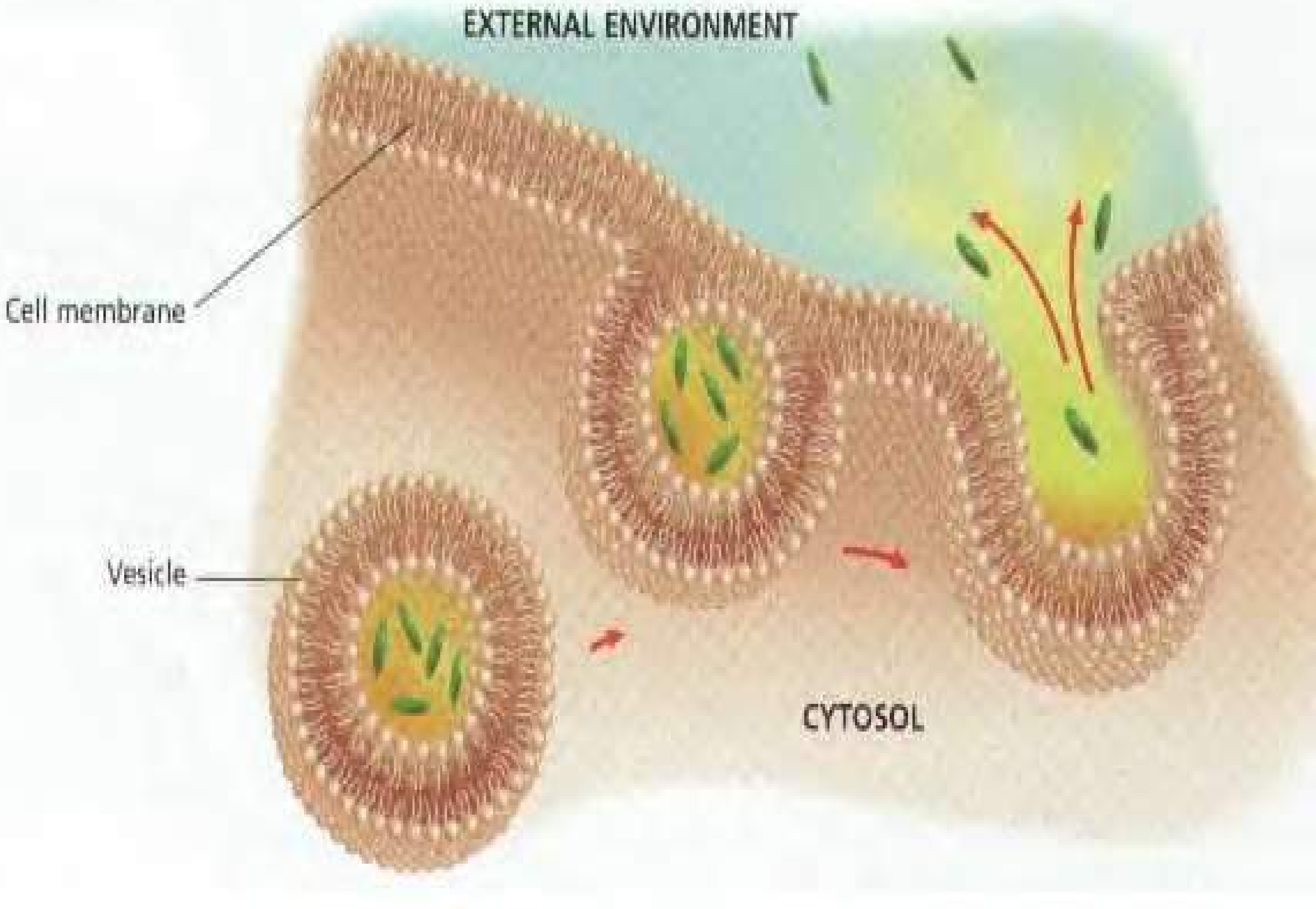
- very LARGE molecules
- Charged molecules (ions)
  - Na^+
  - K^+
  - Cl^-

Movement of squares (low to high concentraion)



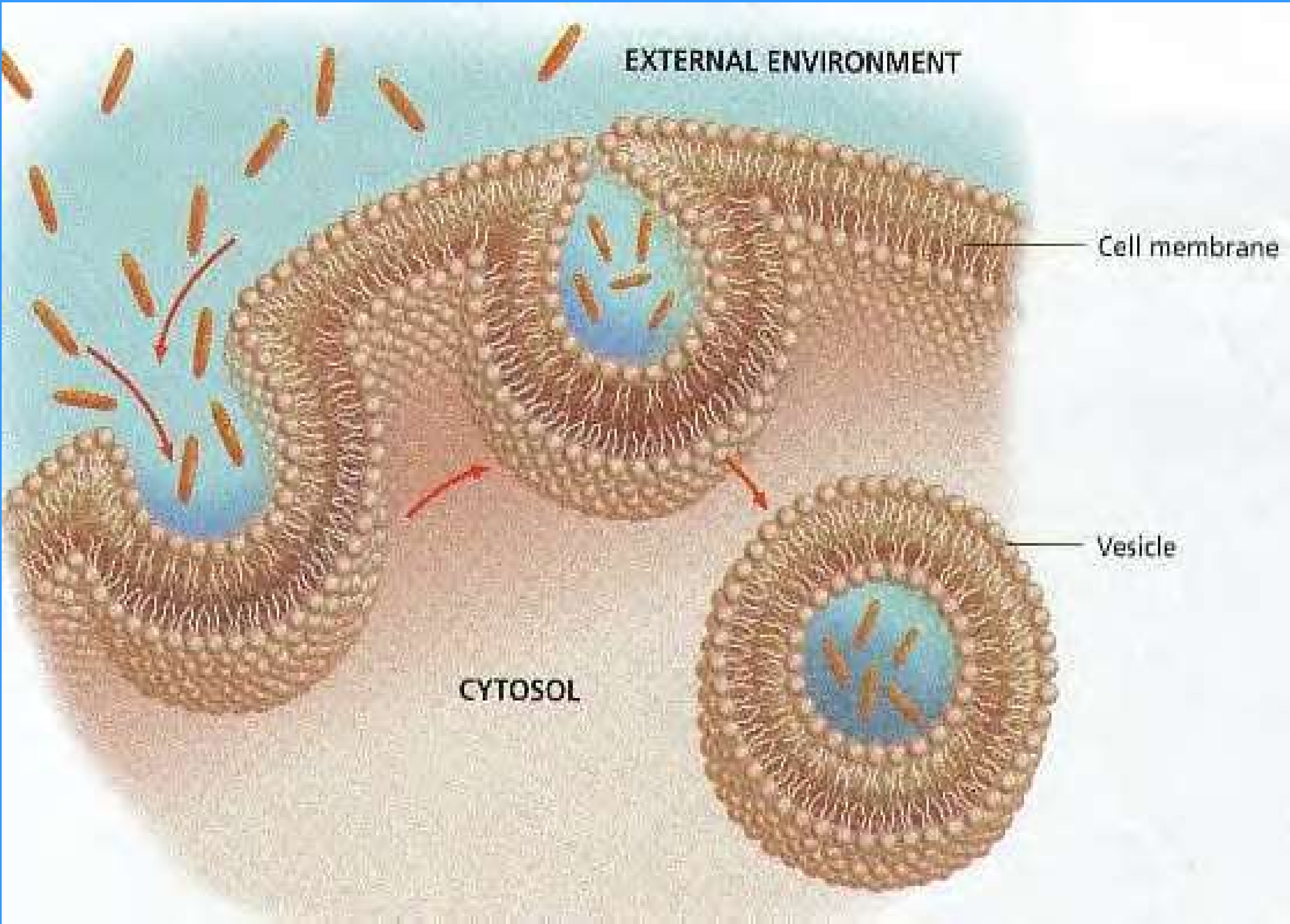
Exocytosis (type of active transport)

- **Movement of large molecules OUT of the cell**
  - **Molecules surrounded by bilayer vesicle (from Golgi)**
  - **Membrane absorbs bilayer vesicle (seals back up)**
  - **Large molecules pushed out**


EXTERNAL ENVIRONMENT
Cell membrane
Vesicle
CYTOSOL

Endocytosis (type of active transport)
Movement of large molecules INTO the cell.

- Membrane starts to make a inward fold (dip)
- Large molecules move into that opening/pocket
- Membrane surrounds the molecules with bilayer (creating a vesicle)
- Vesicle (molecules inside it) moves into the cell
- Membrane seals back up


EXTERNAL ENVIRONMENT
Cell membrane
Vesicle
CYTOSOL

Summary of Passive vs. Active Transport

Passive

- NO energy
- High to Low
- Down the concentration gradient
- Diffusion
- Osmosis
- Facilitated Diffusion

Active

- Requires energy (ATP)
- Low to High
- Up the concentration gradient
- Endocytosis
- Exocytosis

Summary of Passive vs. Active Transport

Passive

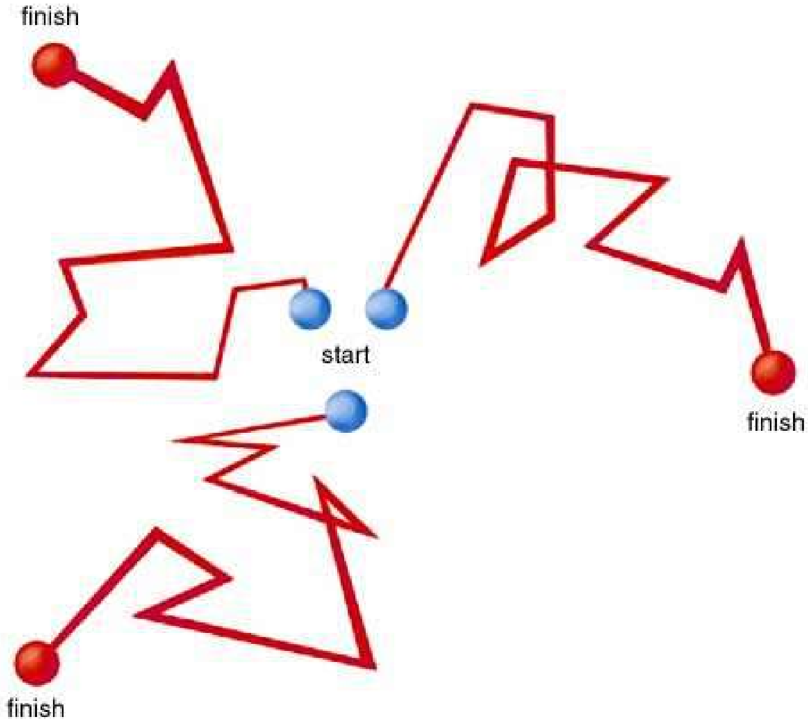
- Can move….
- Small molecules
- Uncharged molecules
- Water
- Gases
  - Carbon Dioxide
  - Oxygen

Active

- Can move….
- LARGE molecules
- Charged molecules (ions: Na^+, K^+, Cl^-)

Molecules are always moving

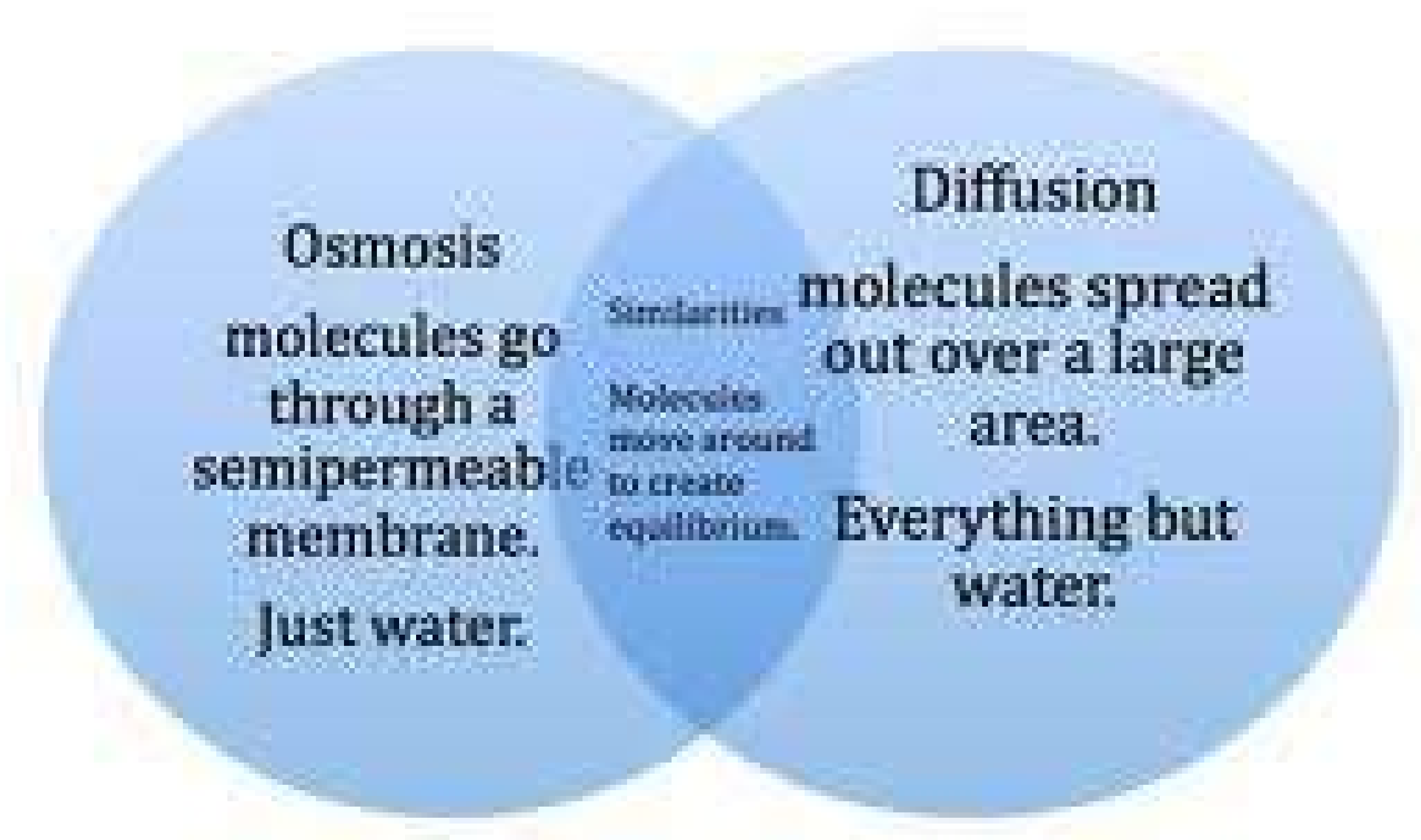
Molecules move randomly and bump into each other and other barriers



Equilibrium

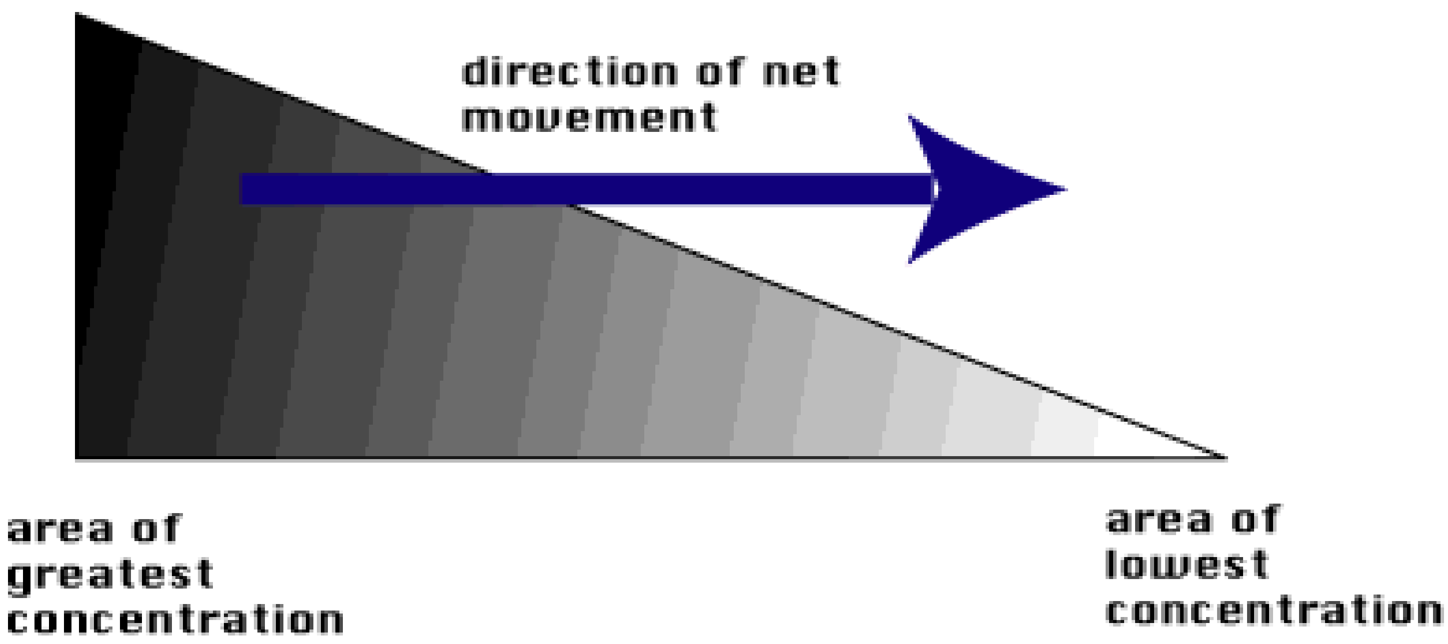
- Diffusion stops at **equilibrium** (when the concentrations across a membrane are equal).
- The movement of molecules continues at equilibrium but the # of molecules moving across the membrane remains the same.
- The rate of transport is dependent on:
  - 1) if the material is solid, liquid or gas.
  - 2) the size of the molecules.
  - 3) temperature
- Examples of molecules that can diffuse through the bilayer: carbon dioxide, oxygen, water but very, very slowly.

OSMOSIS and DIFFUSION



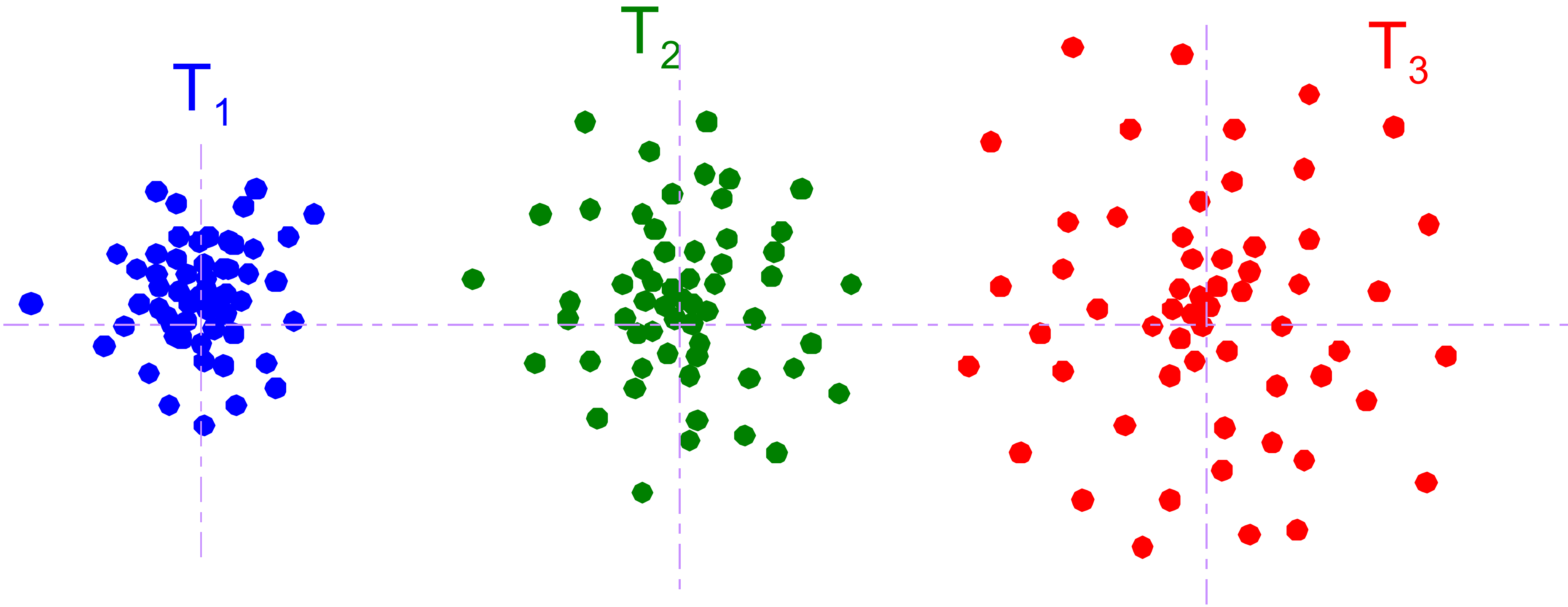
Concentration gradient

Concentration Gradient - change in the concentration of a substance from one area to another.



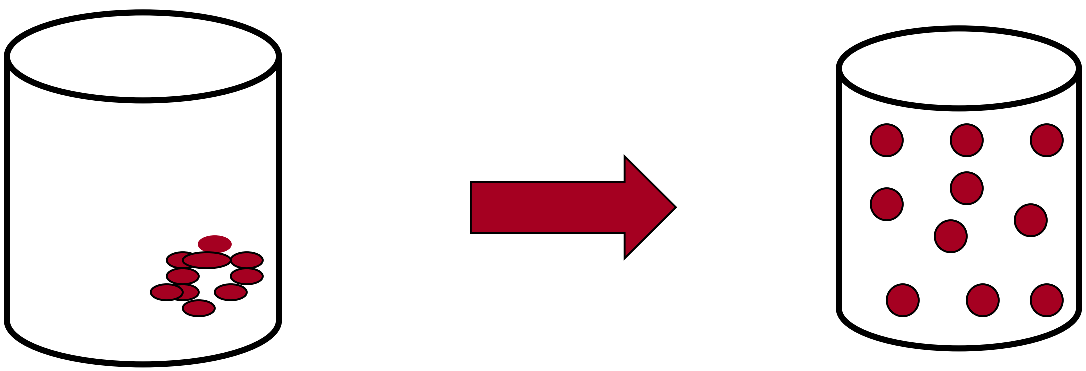
Diffusion

Molecules in solution tend to slowly spread apart over time. This is *diffusion*.



Diffusion

- Movement of molecules from an area of high concentration to an area of lower concentration.
- Factors that affect the rate of diffusion: size of molecules, size of pores in membrane, temperature, pressure, and concentration.



Diffusion

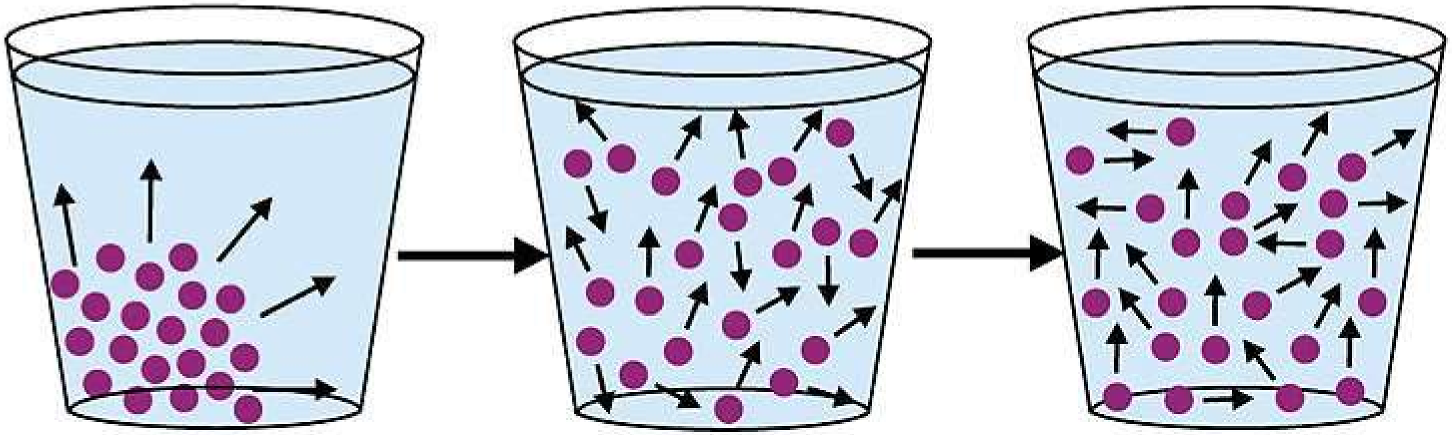


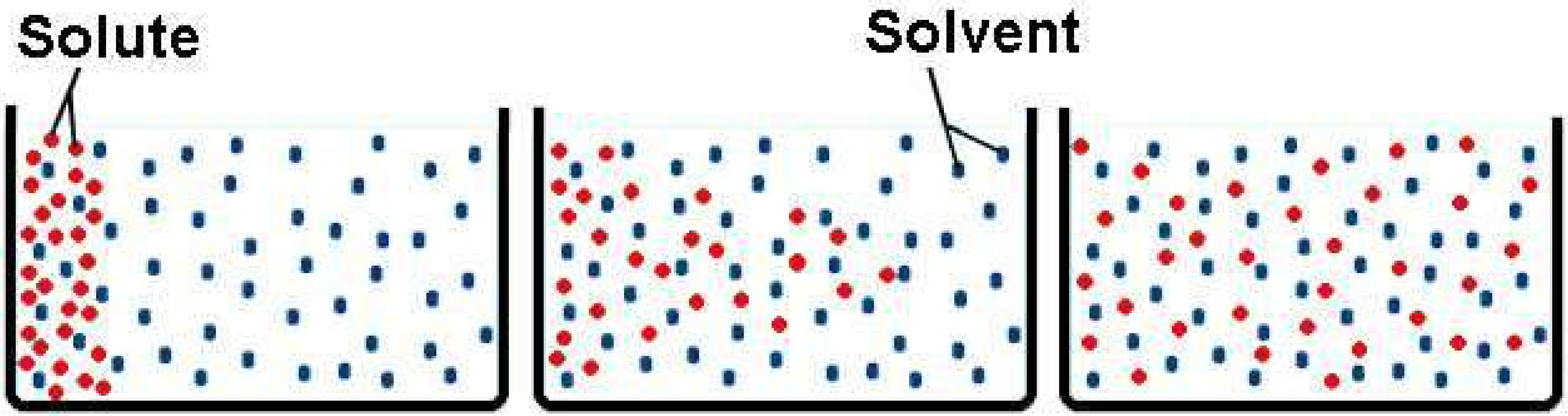
Figure 2.9 Molecular movement during diffusion. Although molecules move in every direction, the overall direction of movement is outward to areas of lower concentration. The colored circles in these figures represent molecules of dye.

concentrated, high energy molecules

[High] ⟶ [Low]

diffuse, low energy molecules

Diffusion will continue until ***equilibrium*** is reached. This means there will be an equal distribution of molecules throughout the space. This is why food coloring moves throughout a beaker of water; why odors smell strong at first and then disappear over time.



Equilibrium, a result of diffusion, shows the uniform distribution of molecules of different substances over time as indicated in the above diagram.

Diffusion in living organisms

- Diffusion in living organisms occurs continuously and it does not always take place across a membrane (e.g. cell membranes).
- Diffusion is important in moving materials in and out of the cells.

Diffusion in living organisms

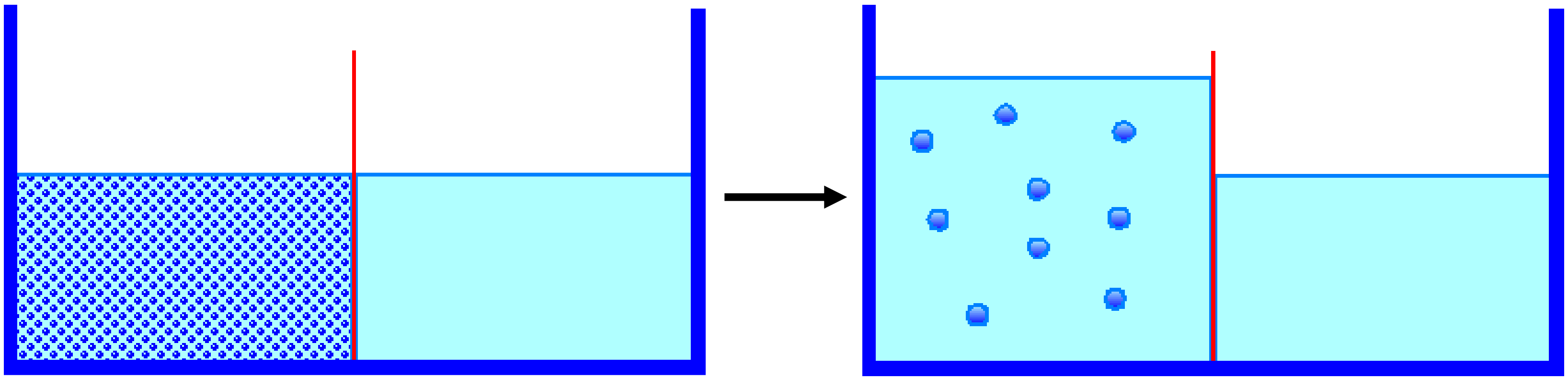
- Diffusion through a partially permeable membrane
  - A **partially permeable membrane** is a membrane that allows some molecules to pass through but not others.
  - The cell surface membrane in plants is an example of a partially permeable membrane.
    - Gases (e.g. oxygen) and smaller molecules (e.g. sugar) diffuse into the plants cells through the membrane.
  - In humans, gaseous exchange occurs in the lungs by diffusion.
    - When we breathe in, oxygen enters the air sacs in our lungs.
    - The oxygen concentration is higher in the air sacs than in the blood surrounding them.
    - Thus, oxygen diffuses out of the air sacs into the bloodstream.

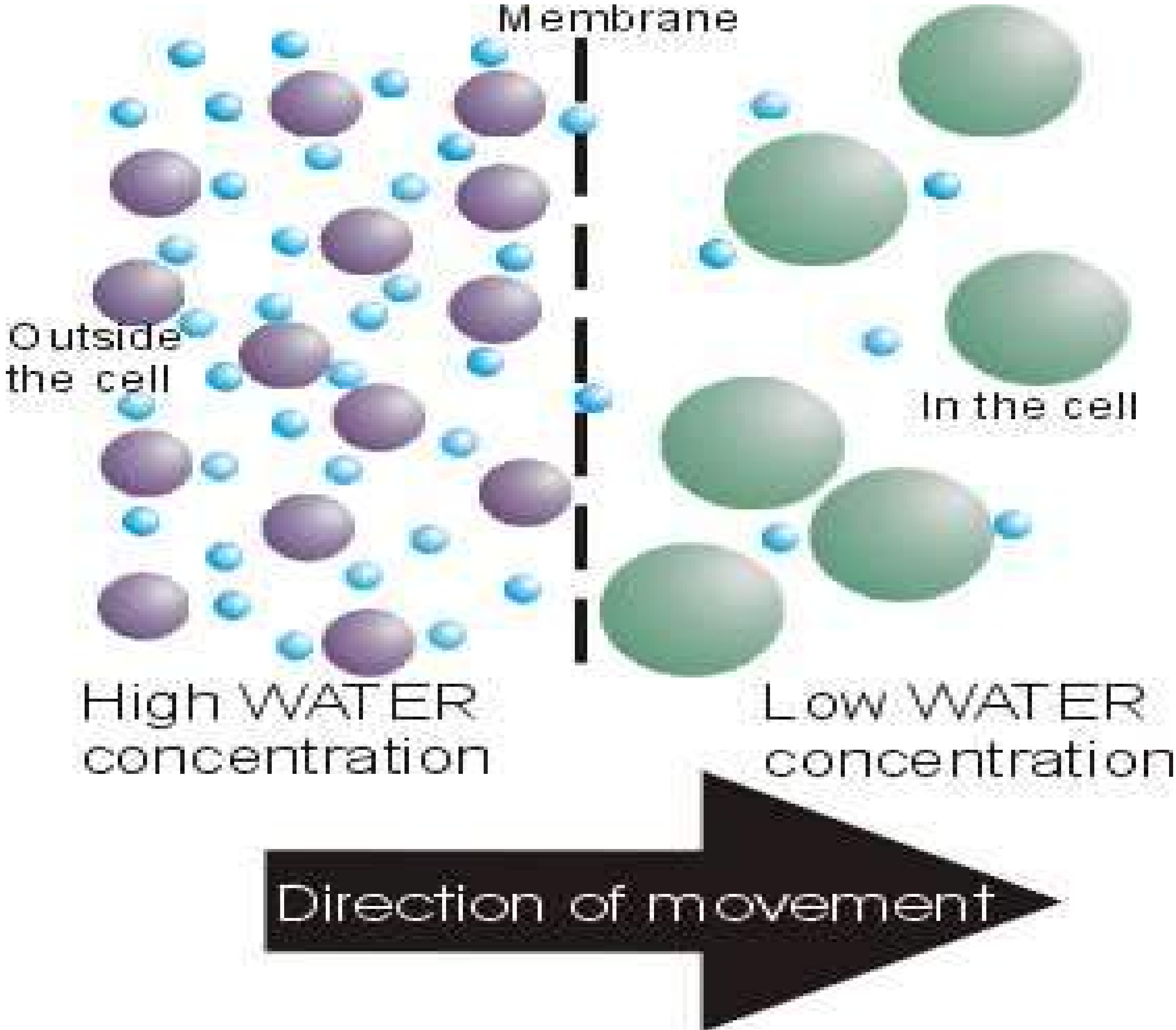
Diffusion in living organisms

- Diffusion through a partially permeable membrane
  - In humans, gaseous exchange occurs in the lungs by diffusion.
    - During respiration in the cells, carbon dioxide is produced as waste.
    - Carbon dioxide is carried in the bloodstream leading to the lungs.
    - It then diffuses out into the air sacs, and leaves the body when we breathe out.

Osmosis

- Osmosis is the movement of ***WATER*** across a semi-permeable membrane
- At first the concentration of solute is very high on the left.
- But over time, the water moves across the semi-permeable membrane and dilutes the particles.



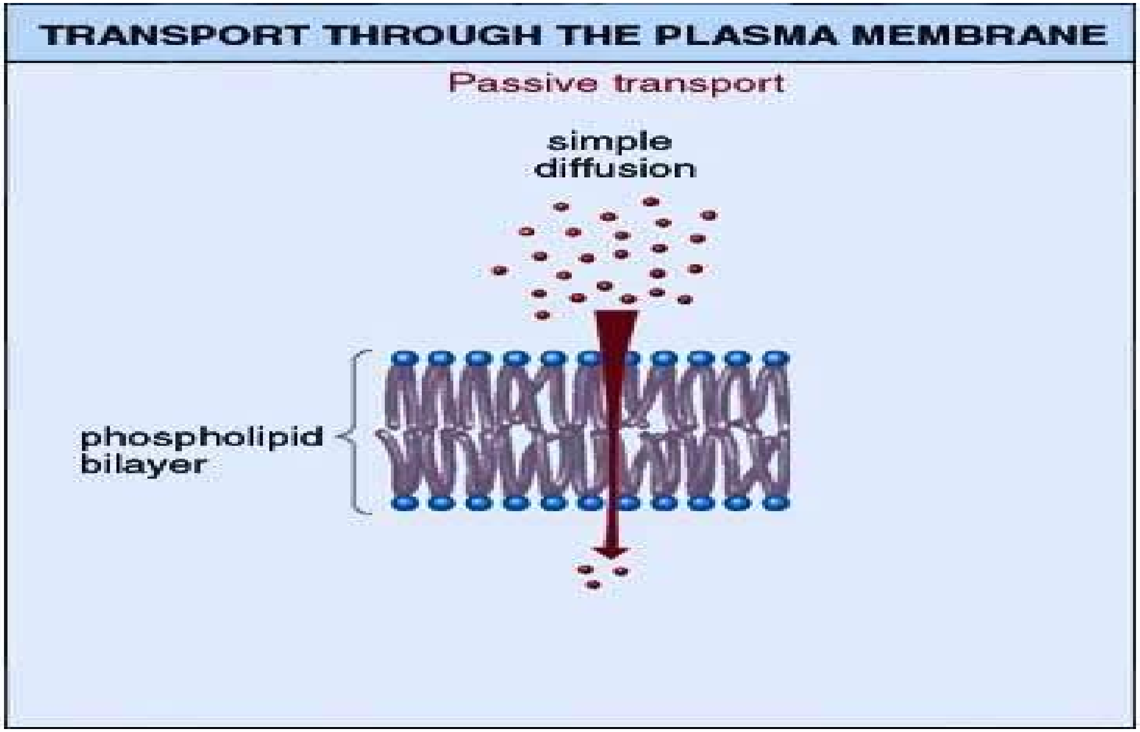

Membrane
Outside the cell
In the cell
High WATER concentration
Low WATER concentration
Direction of movement

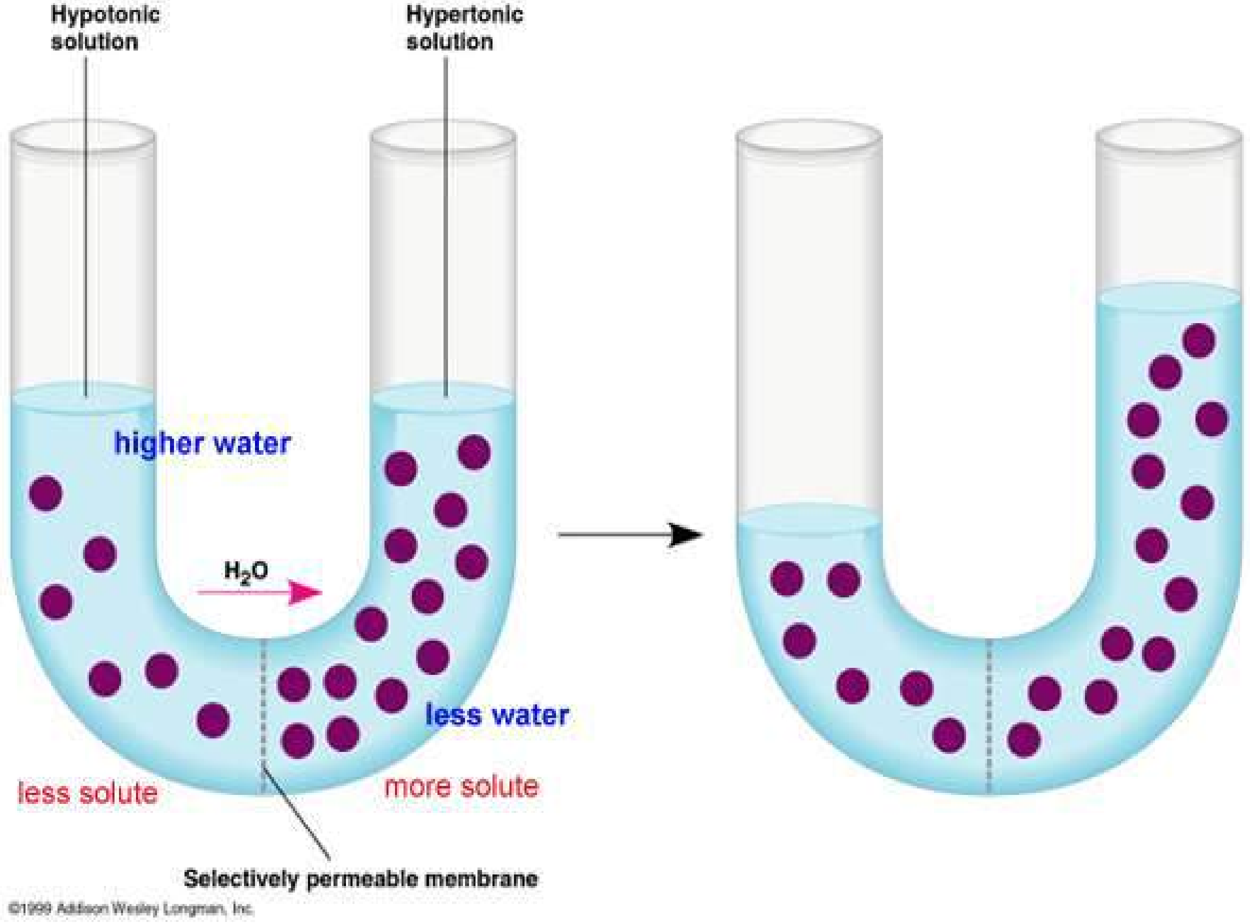
Osmosis – A Special kind of Diffusion

Diffusion of water across a selectively permeable membrane (a barrier that allows some substances to pass but not others). The cell membrane is such a barrier.

Small molecules pass through – ex: water

Large molecules can't pass through – ex: proteins and complex carbohydrates

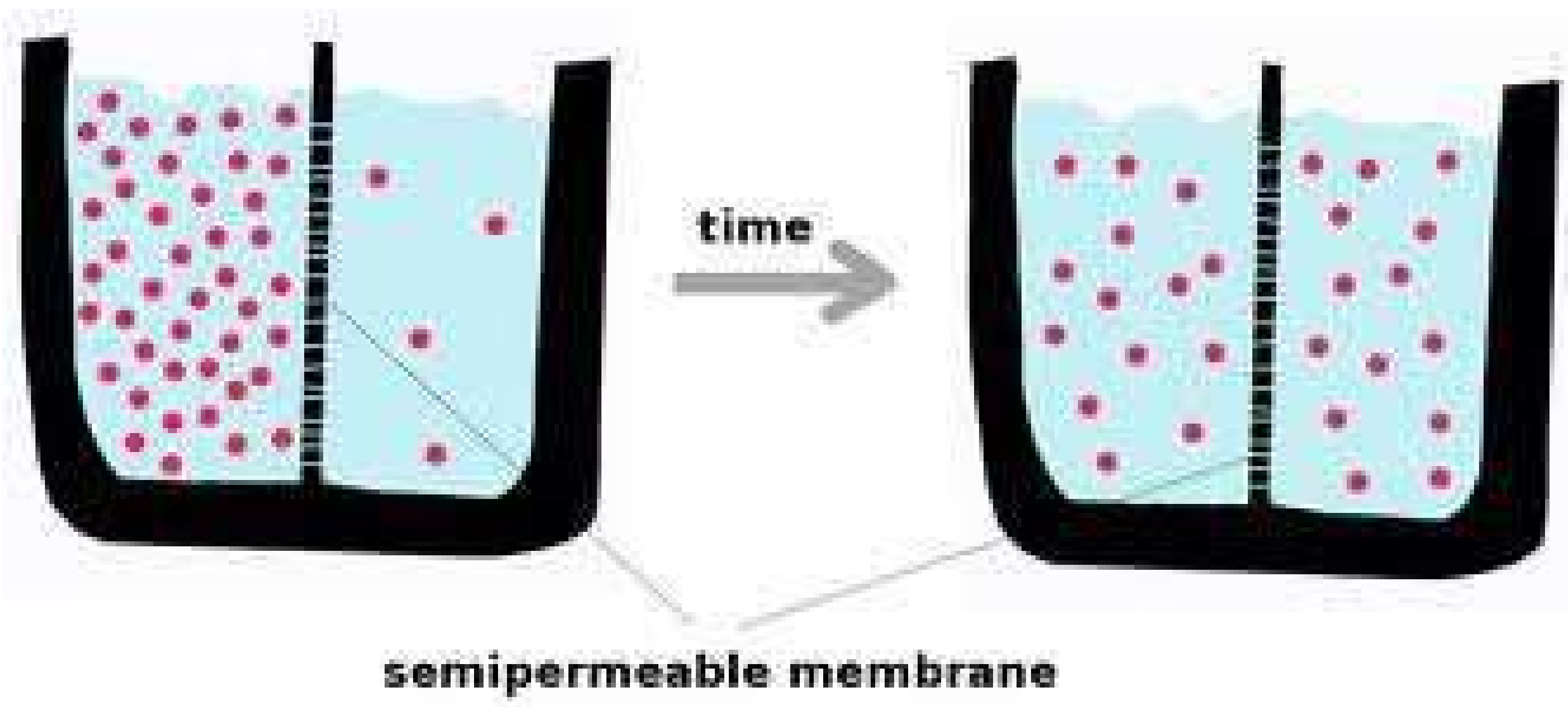




Hypotonic – The solution on one side of a membrane where the solute concentration is less than on the other side. **Hypotonic Solutions** contain a low concentration of solute relative to another solution.

Hypertonic – The solution on one side of a membrane where the solute concentration is greater than on the other side. **Hypertonic Solutions** contain a high concentration of solute relative to another solution.

Over time molecules will move across the membrane until the concentration of solutes is equal on both sides. This type of solution is called ***ISOTONIC***.



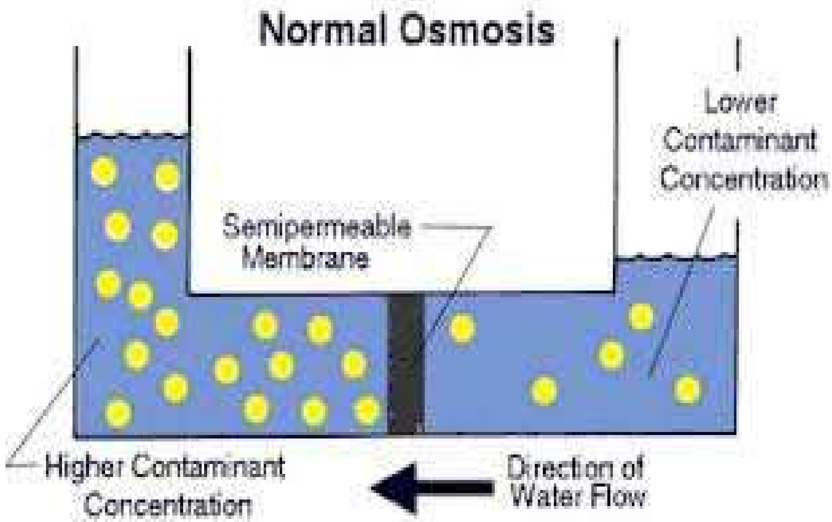
- Cytoplasm is a solution of water and solids (solutes dissolved in the water).
- Water moves into and out of cells because of the different concentrations of the solutes.
- Different kinds of cells react differently depending on the solution they are in.

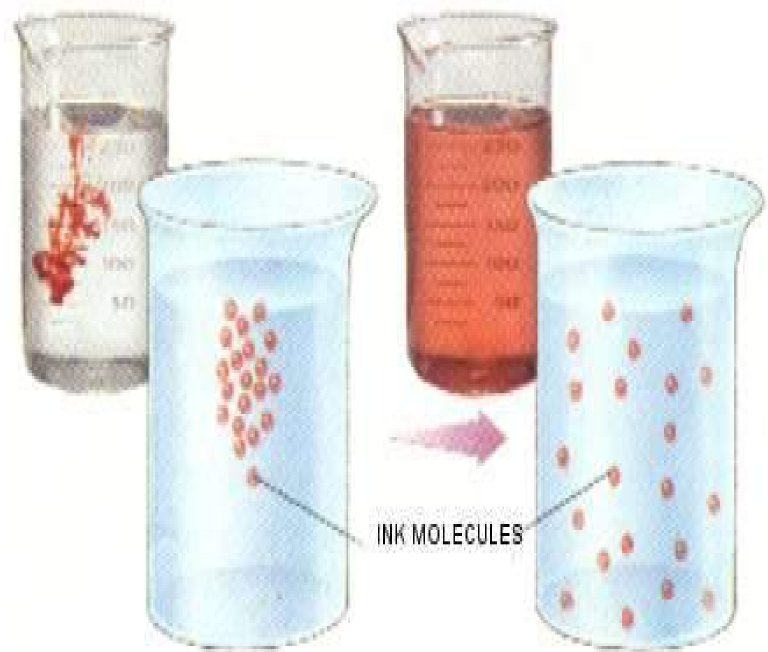
PASSIVE TRANSPORT

Passive transport occurs without expenditure of energy. Molecules move using their own kinetic energy . Diffusion and osmosis are examples of passive transport. Passive transport allows cells to get water, oxygen and other small molecules that they need. It also allows the cell to get rid of waste such as carbon dioxide.

DIFFUSION

OSMOSIS





Why are osmosis & diffusion important?

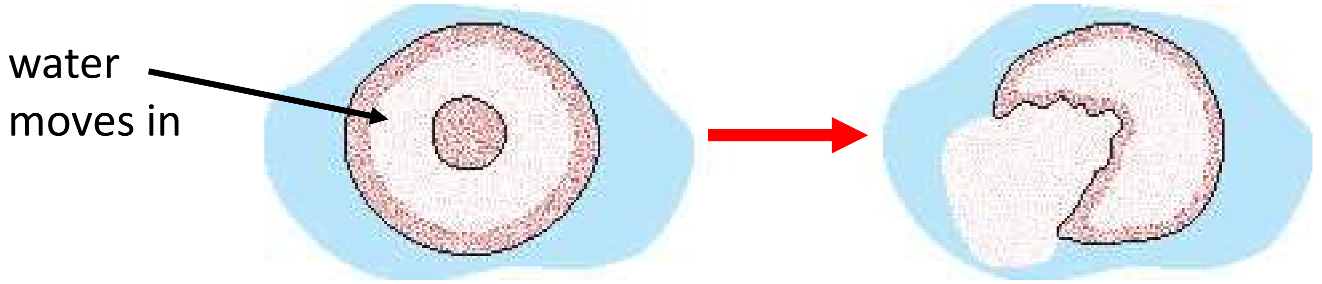
- All living things have certain requirements they must satisfy in order to remain alive. These include exchanging gases (usually CO2 and O2), taking in water, minerals, and food, and eliminating wastes. These tasks ultimately occur at the cellular level, and require that molecules move through the membrane that surrounds the cell.

Osmosis in living organisms

- Recall some properties of cells:
  - Cell membrane of both plant and animal cells is partially permeable.
  - The plant cell wall is made of cellulose. It is permeable.

Osmosis in living organisms

- What happens to animal cells when they are placed in distilled water?
- **Animal cells**
  - Animal cells have elastic membranes. When the water molecules flow in, the animal cells will swell and eventually burst.



Water potential outside the cell is higher than that in the cytoplasm.

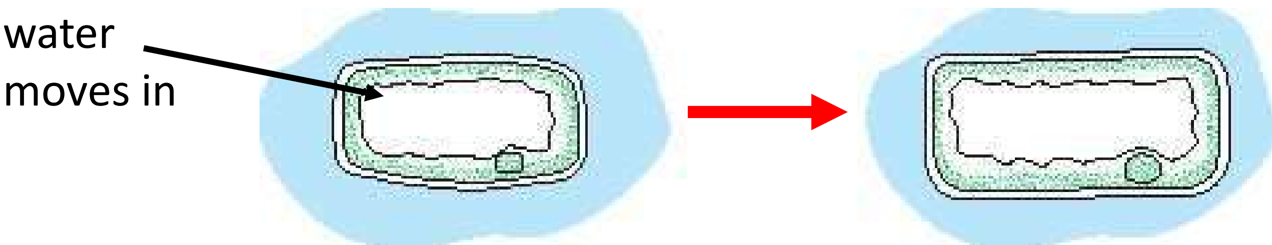
Cell expands and eventually bursts.

Osmosis in living organisms

- What happens to plant cells when they are placed in distilled water?
- **Plant cells**
  - Plant cells have strong, rigid cells walls which prevent the cells from expanding too much.
  - When water molecules flow in, the contents in the cell press the cell wall.
  - The water creates a pressure on the cell wall of the plant cell. This is called **turgor pressure** and keeps the plant tissues **turgid**.
  - Soft tissues in plants depend on turgor for support. If plants lose too much water, they will wilt.

Osmosis in living organisms

- **Plant cells**



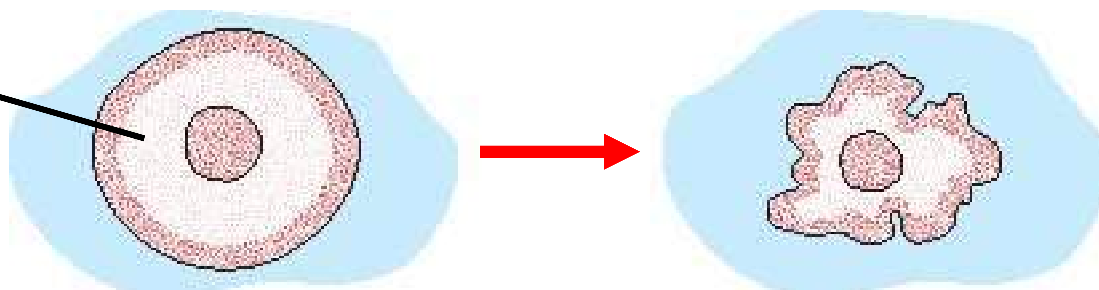
Water potential outside the cell is higher than that in the cell sap.

Cell expands and becomes turgid. The rigid cellulose cell wall expands slightly only. This prevents the cell from bursting.

Osmosis in living organisms

- What happens to animal cells when they are placed in concentrated solution?
- **Animal cells**
  - Animal cells will shrivel up as they lose water.

Water leaves the cell by osmosis



Concentration of water molecules outside the cell is lower than that in the cytoplasm.

Cell shrinks and becomes soft. It is dehydrated.

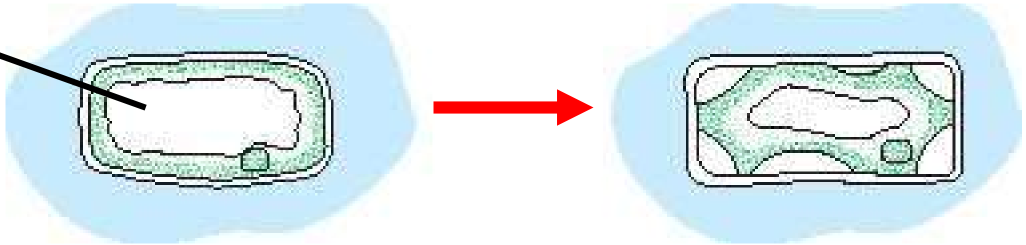
Osmosis in living organisms

- What happens to plant cells when they are placed in concentrated solution?
- **Plant cells**
  - When the concentration of water molecules of the cytoplasm and cell sap is higher than that of the surrounding solution, water leaves the plant cells by osmosis.
  - The vacuoles shrink and the cell contents pulls away from the cellulose cell walls. The plant cells lose turgor pressure and become flaccid.

Osmosis in living organisms

- **Plant cells**

Water leaves the cell by osmosis.

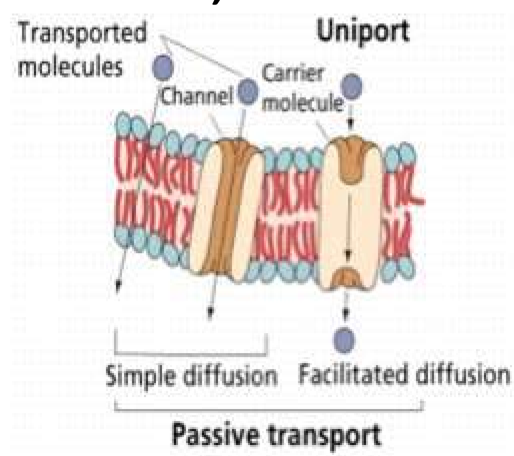


Concentration of the water molecules outside the cell is lower than that in the cell sap.

Cell contents pull away from the cell walls and the cell becomes flaccid.

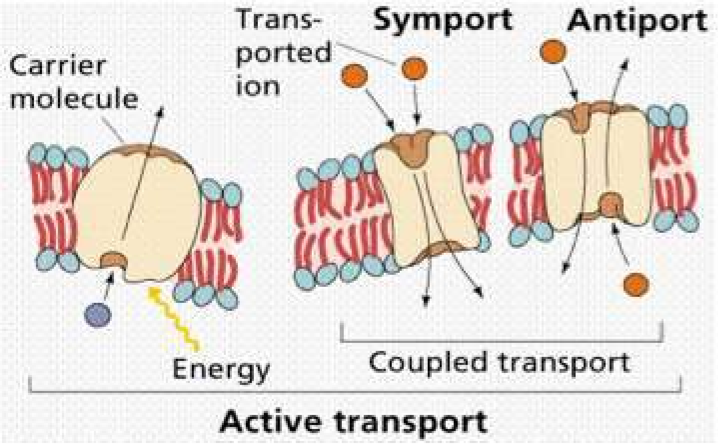
Active and Passive Transport

- Two additional methods by which substances may move through cell membranes include:
  - **Passive transport** requires no energy from the cell.
    - Examples include the diffusion of oxygen and carbon dioxide, osmosis of water, and facilitated diffusion.

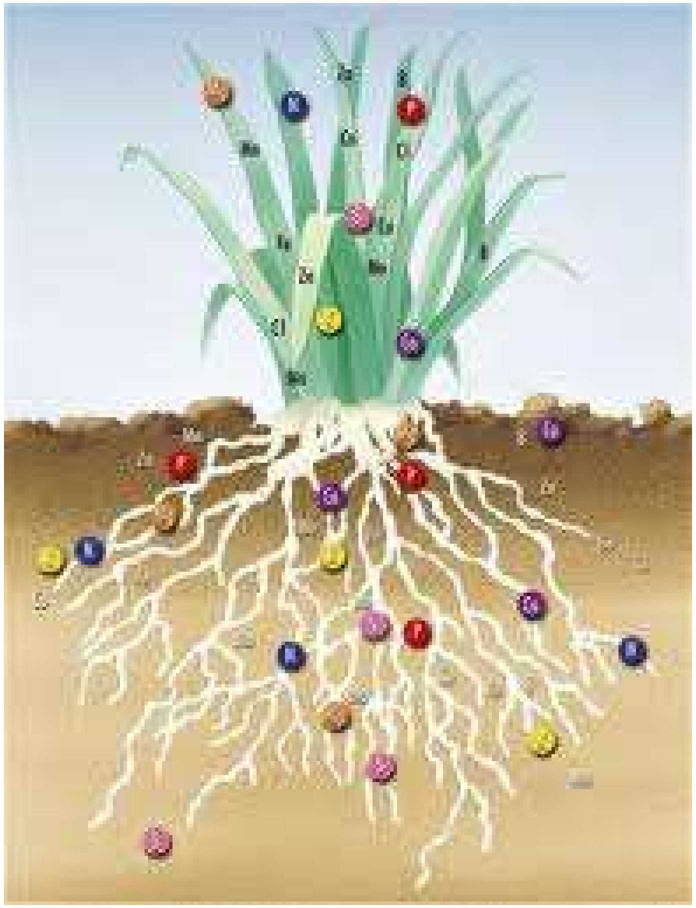


Active and Passive Transport

– **Active transport** requires the cell to spend energy, usually in the form of **ATP**.
  - Examples include transport of large molecules (non-lipid soluble) and the sodium-potassium pump.



THE END



Lecture 7 of biophysics

The Nervous System

- Rapid Communication and Control
  - Sensation
    - receives info. on environmental changes
  - Integration
    - interprets the changes, integrates signals from multiple signals
  - Response
    - induces action from of muscles or glands

Nervous System Organization: General Anatomy

- Central Nervous System (CNS)
  - Brain + Spinal Cord
  - control center (integration)
- Peripheral Nervous System (PNS)
  - cranial nerves and spinal nerves
  - connects CNS to sensory receptors, muscles and glands

The Neuron

- The *neuron* is the basic building block of the nervous system

  - They are often grouped in bundles called *nerves.*

Types of Neurons

- Sensory (Afferent) Neuron - input
  - part of the PNS
  - transmit electrical signals from tissues and organs to CNS
    - detect changes in environment

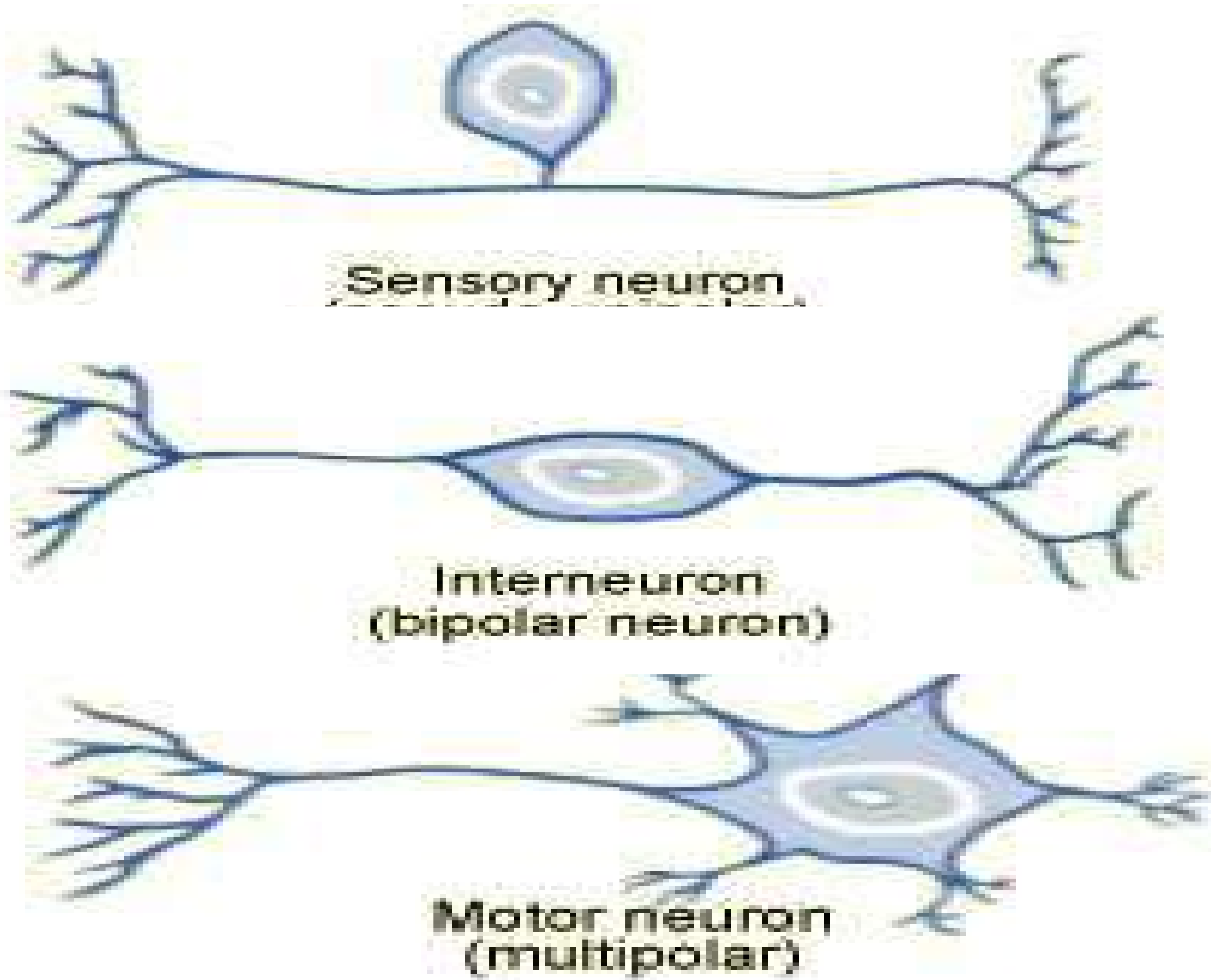
Types of Neurons

- Motor (Efferent) neuron - output
  - part of the PNS
  - transmit signals from CNS to efferent tissues (muscle, gland cells)
  - somatic motor neurons
    - skeletal muscle contraction
  - autonomic motor neurons
    - smooth muscle, cardiac muscle, and glands

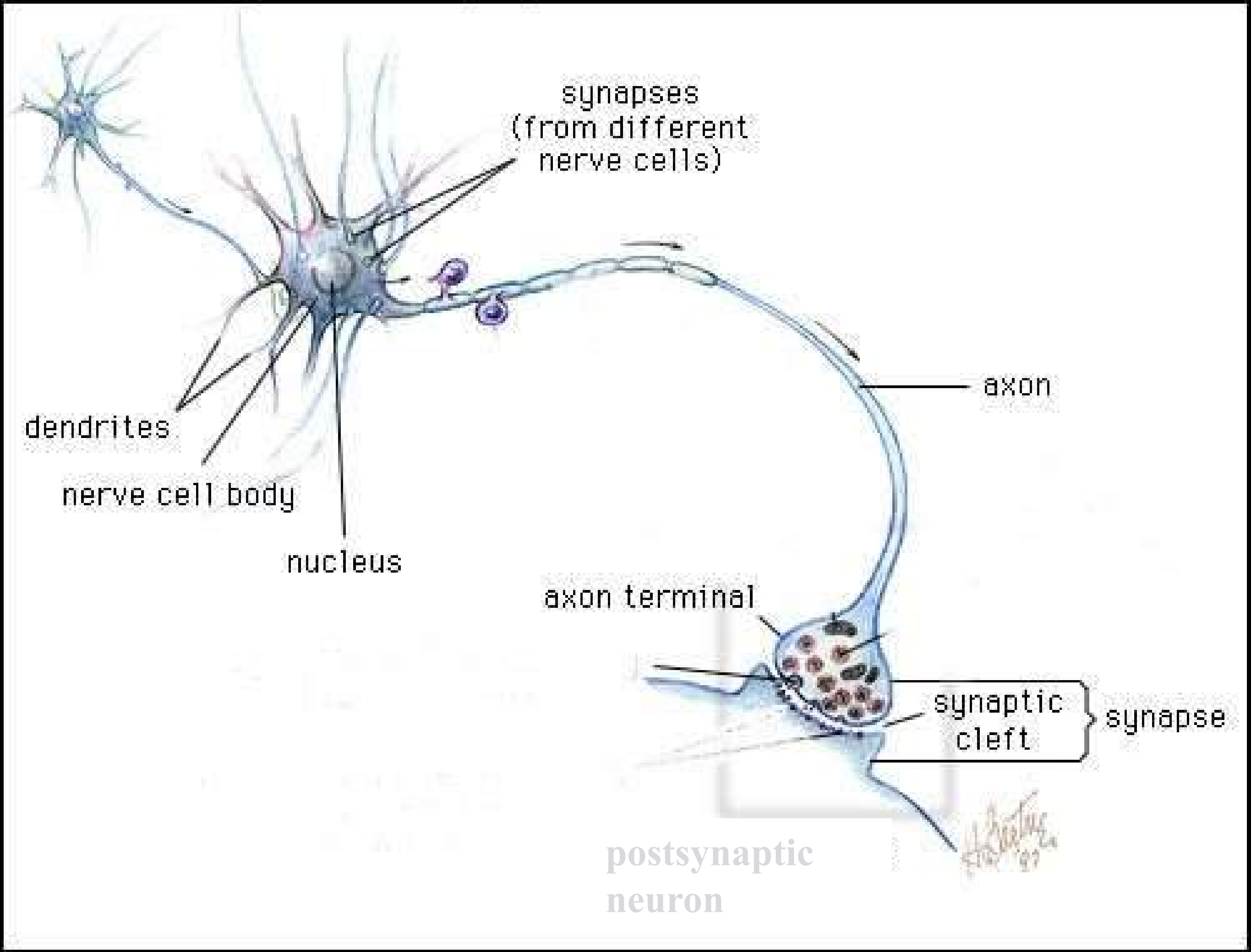
Types of Neurons

- Interneurons
  - 99% of all neurons
  - connect afferent to efferent
  - located entirely in the CNS

Types of neuron cell



Neuron Forming a Chemical Synapse



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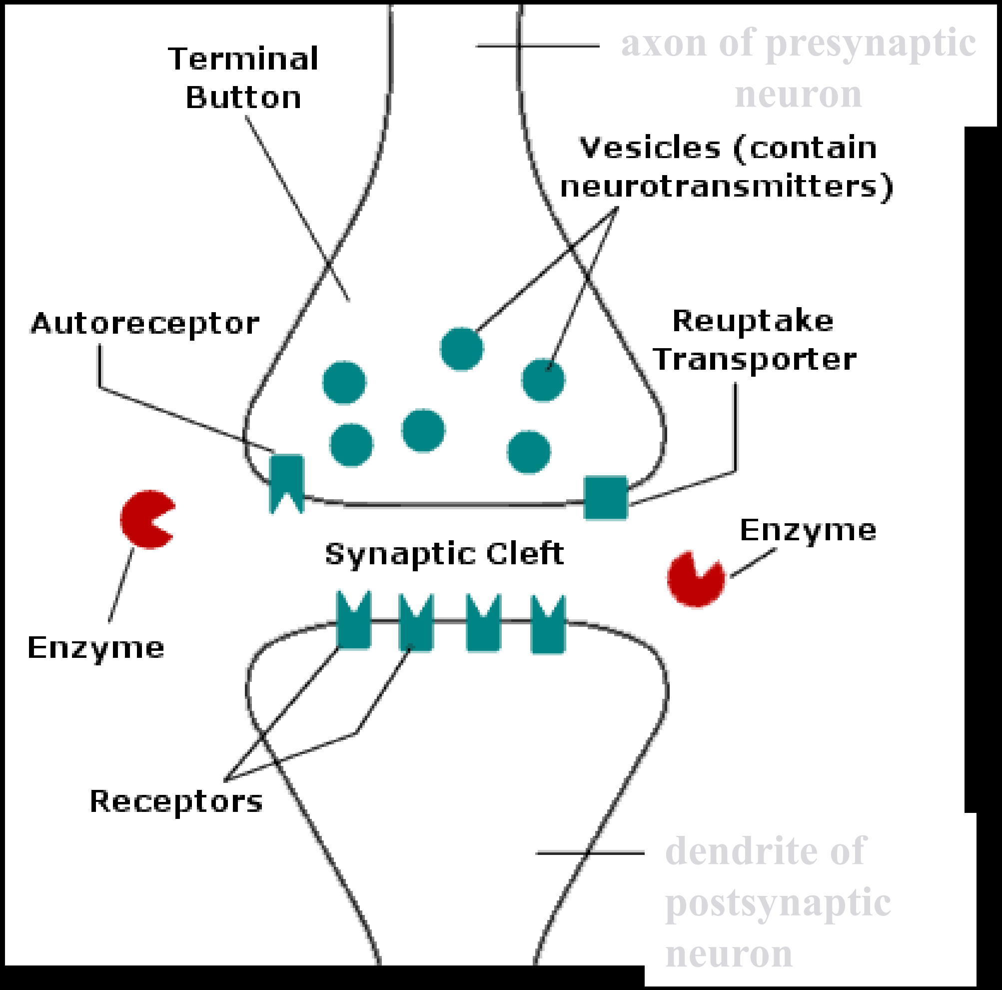
Synapse



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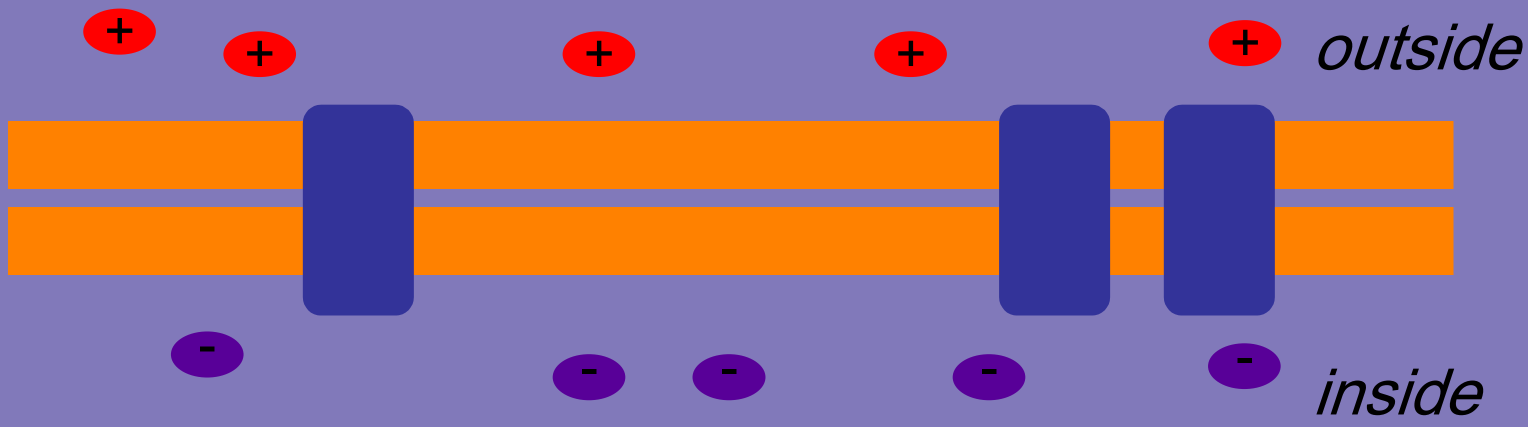
The Membrane

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

The Resting Potential

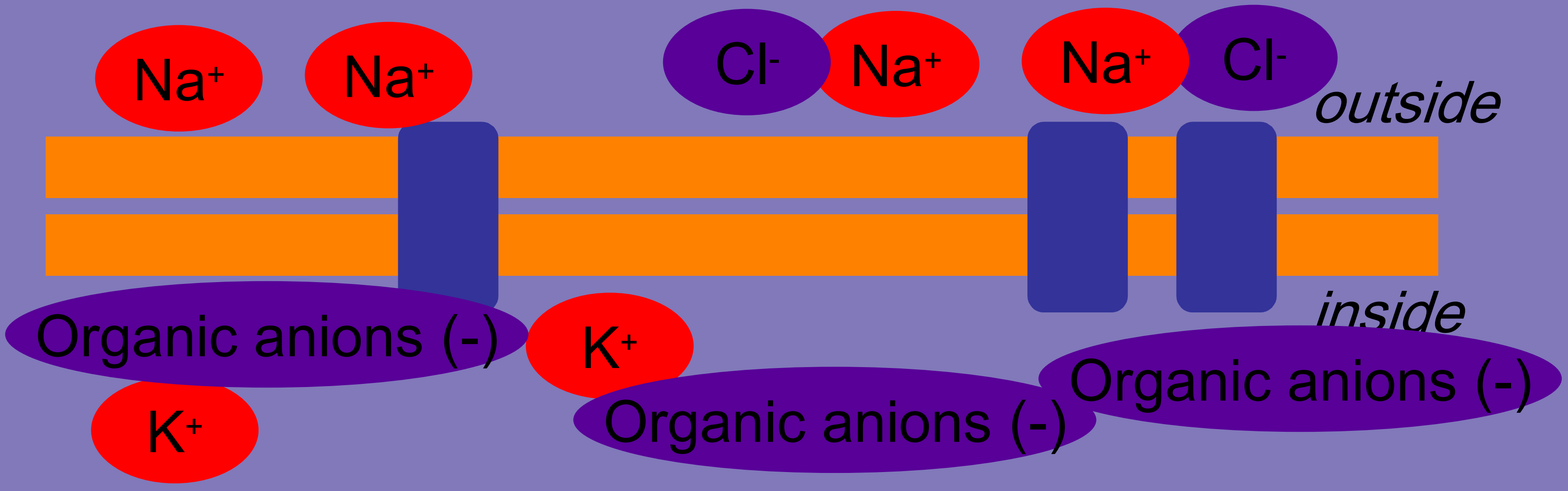
- There is an **electrical charge** across the membrane.
- This is the **membrane potential**.
- The **resting potential** (when the cell is not firing) is a 70mV difference between the inside and the outside.



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.



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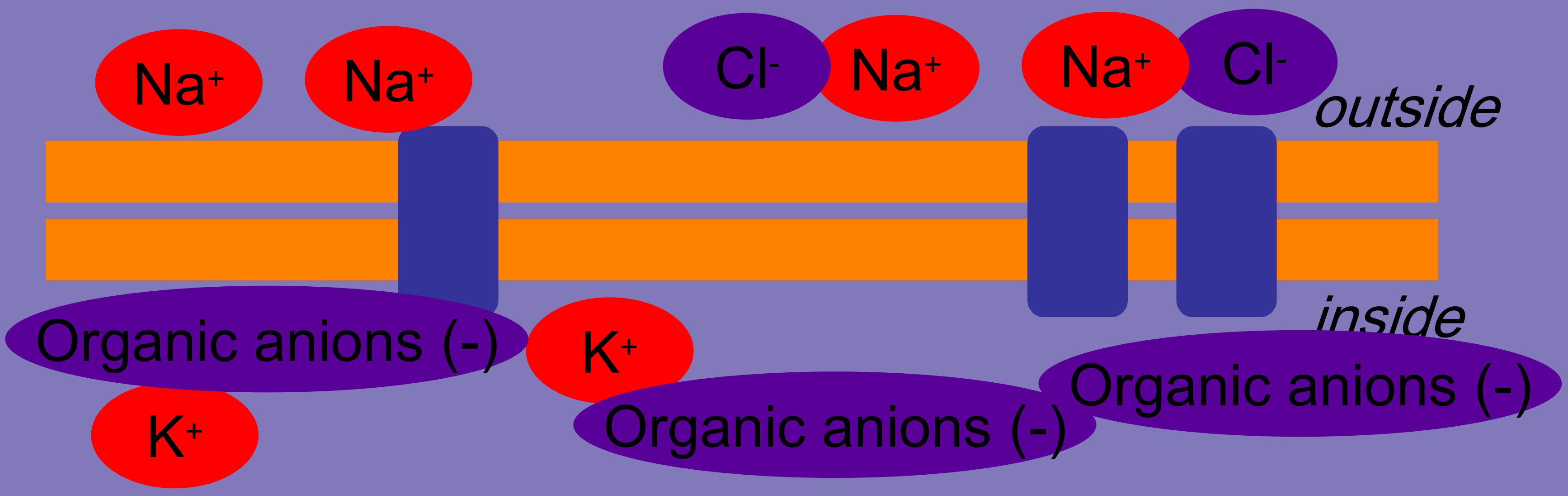
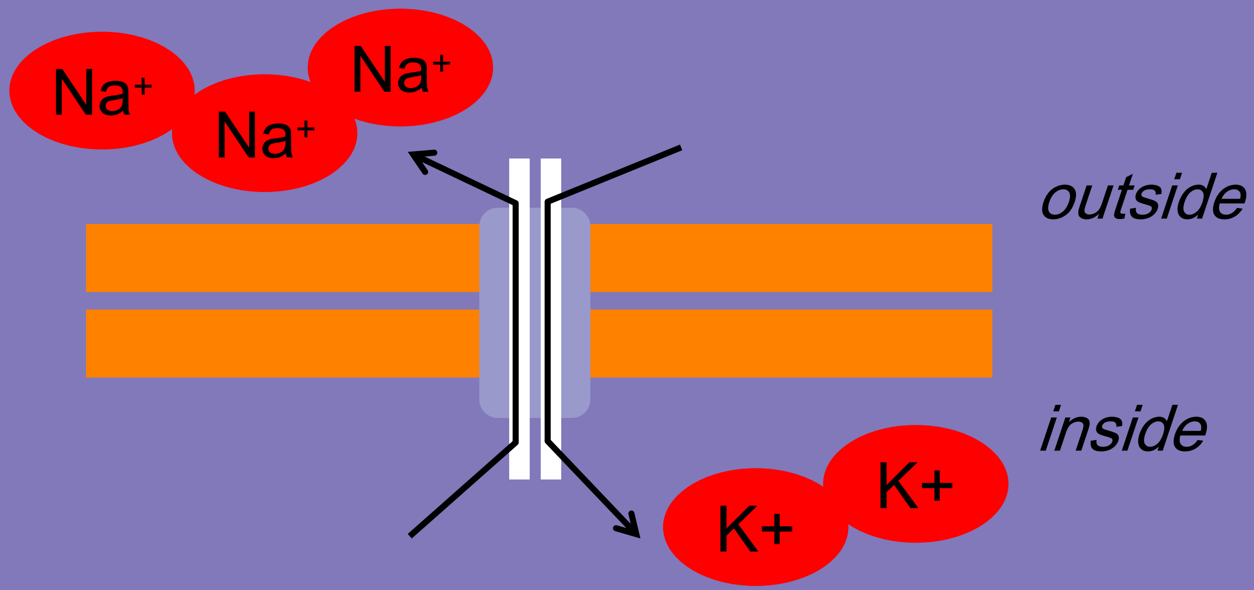


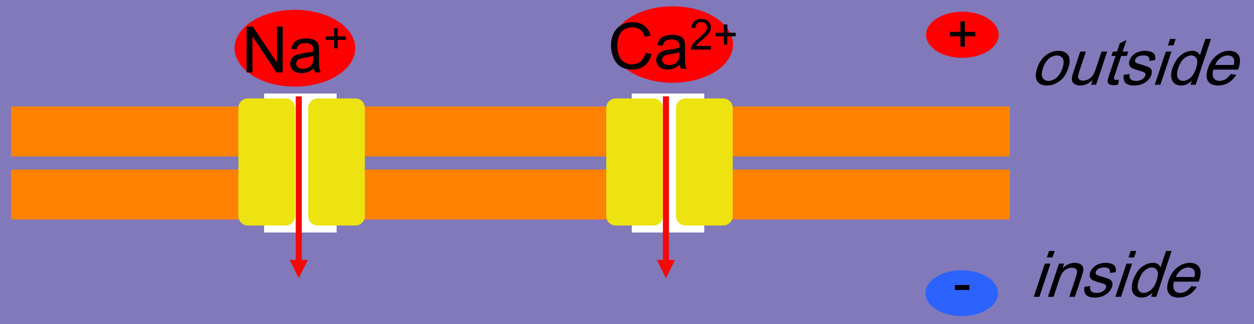
Maintaining the Resting Potential

- 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.



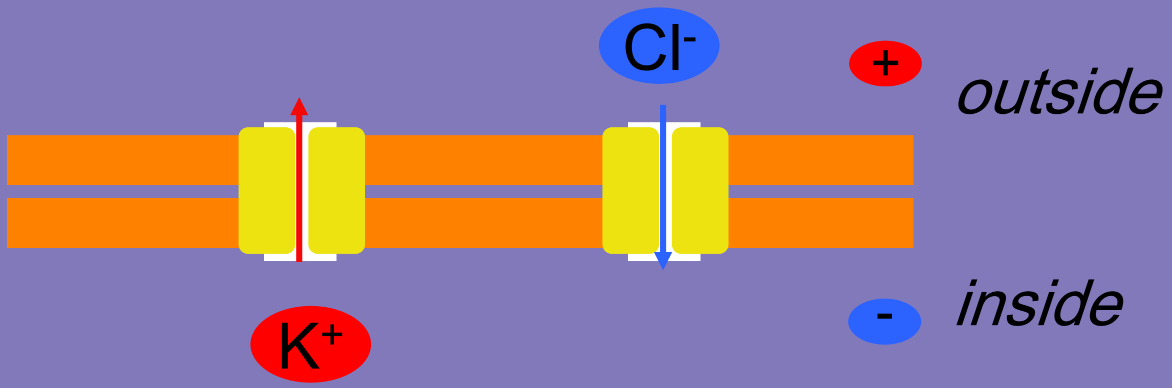
Excitatory postsynaptic potentials (EPSPs)

- Opening of ion channels which leads to **depolarization** makes an action potential *more likely*, hence “excitatory PSPs”: **EPSPs.**
  - Inside of post-synaptic cell becomes **less negative**.
  - **Na^+ channels** *(NB remember the action potential)*
  - **Ca^{2+}** . (Also activates structural intracellular changes -> learning.)

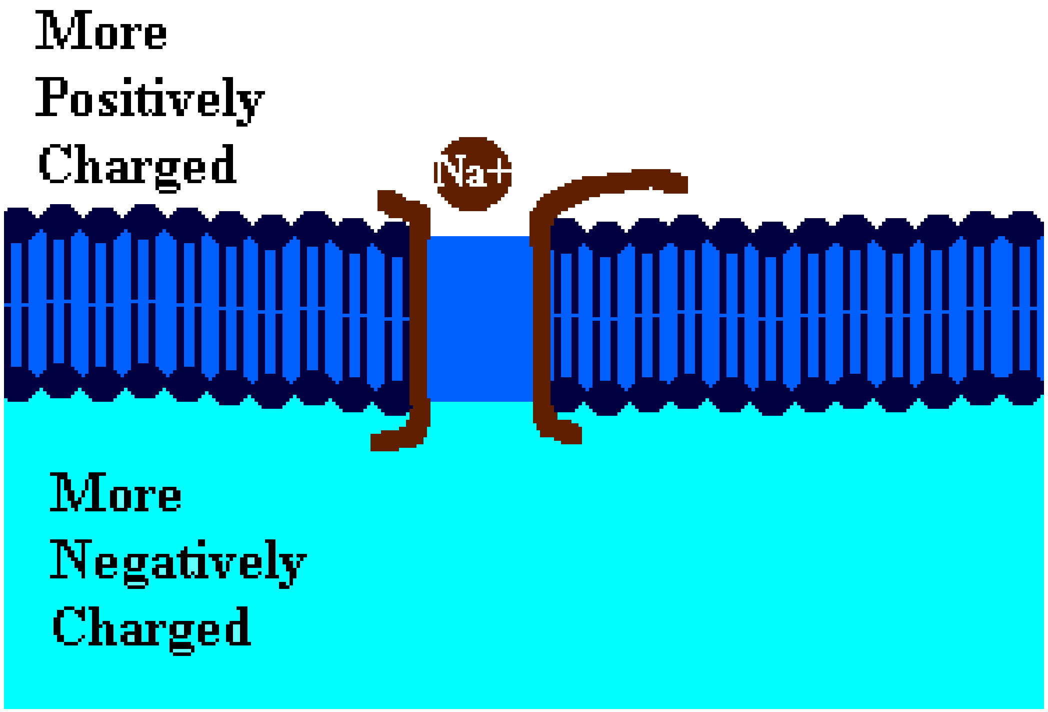


Inhibitory postsynaptic potentials (IPSPs)

- Opening of ion channels which leads to **hyperpolarization** makes an action potential *less likely*, hence "inhibitory PSPs": **IPSPs.**
  - Inside of post-synaptic cell becomes **more negative**.
  - **K^+** *(NB remember termination of the action potential)*
  - **Cl^-** (if already depolarized)

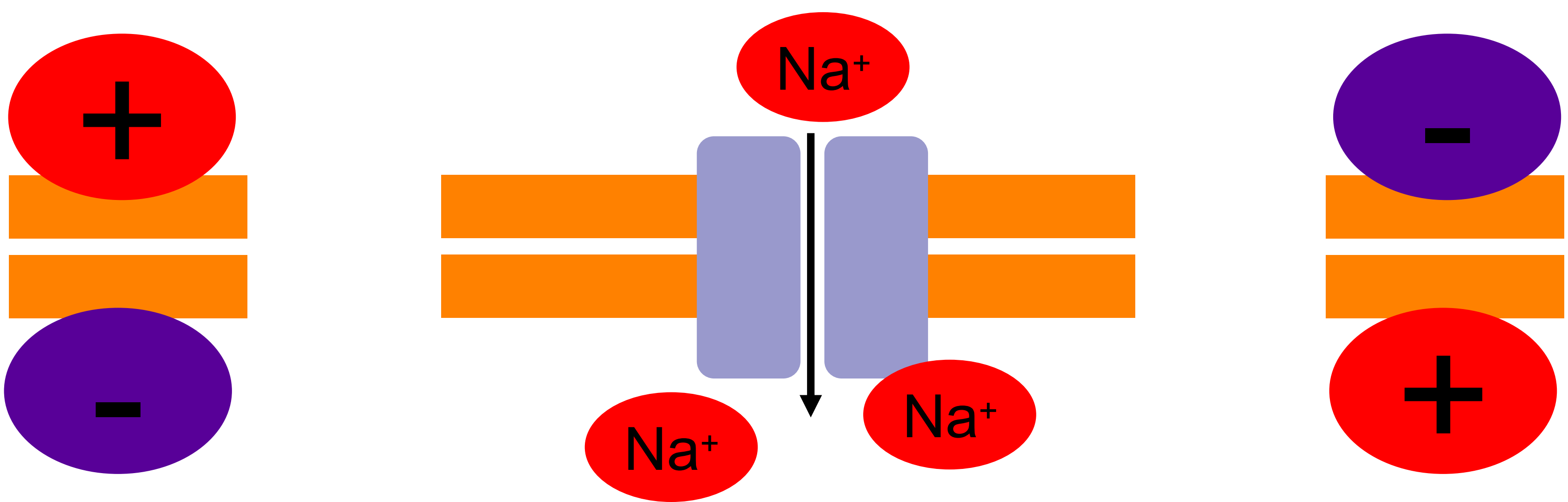


Before Depolarization

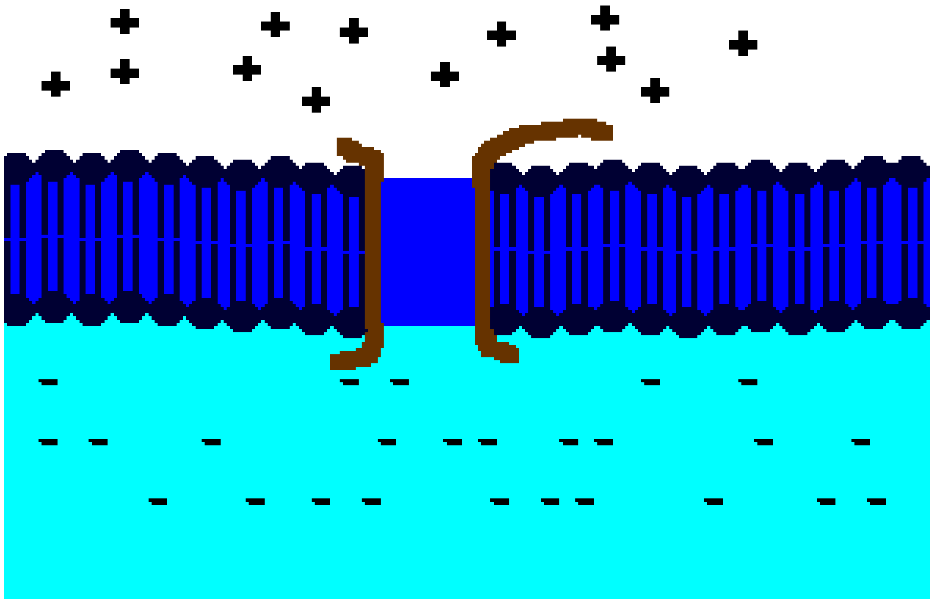


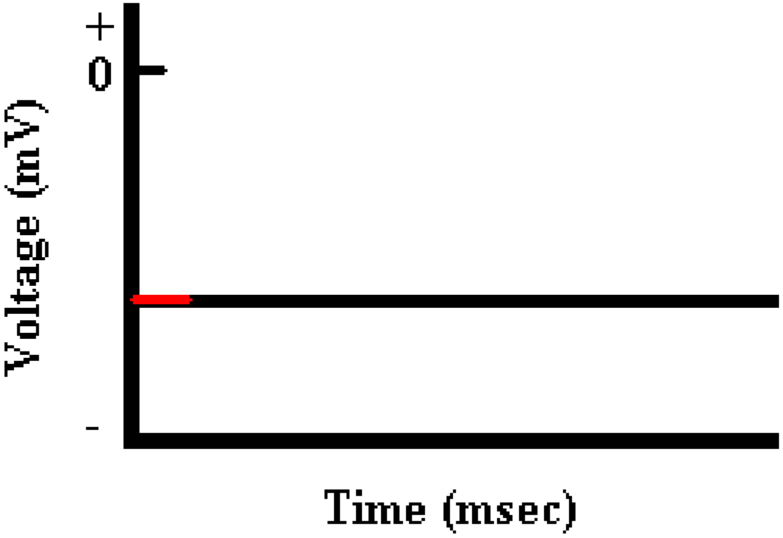
Action potentials: Rapid depolarization

- 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.



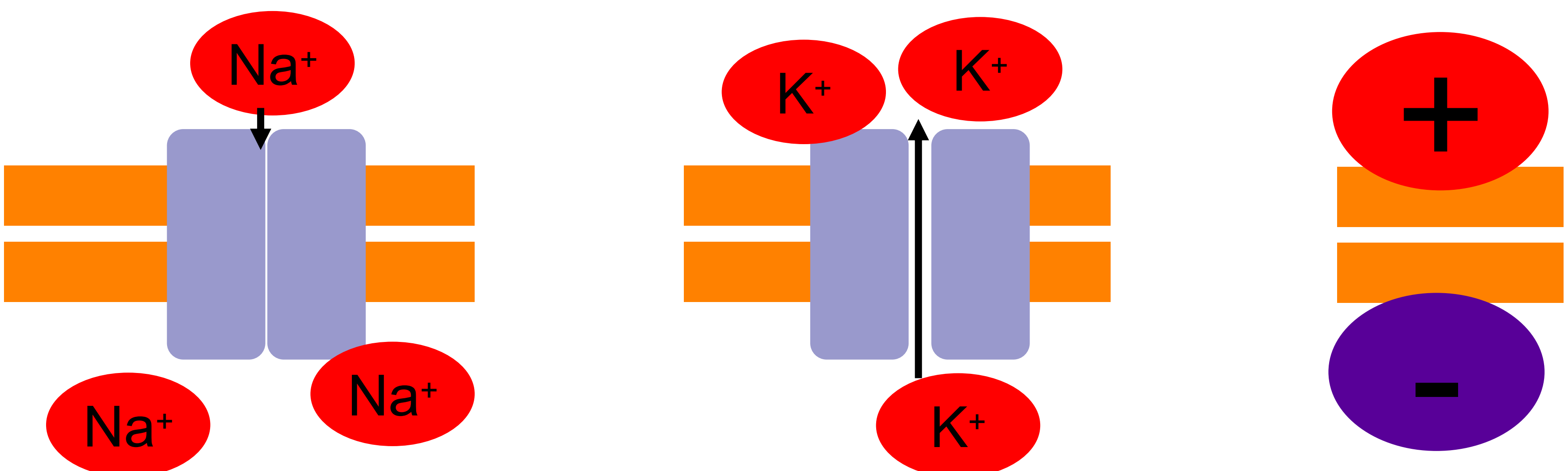
Depolarization



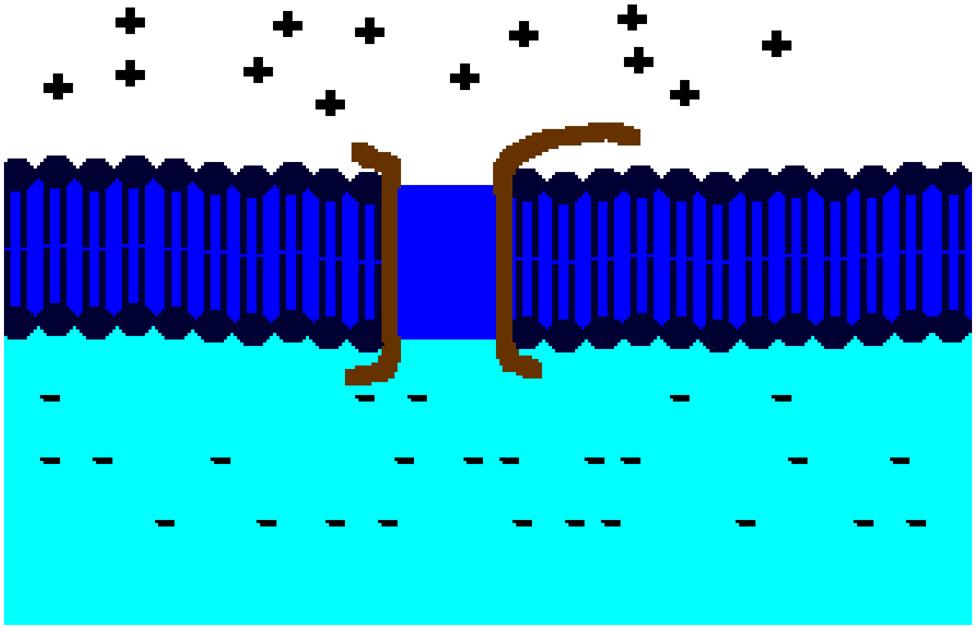


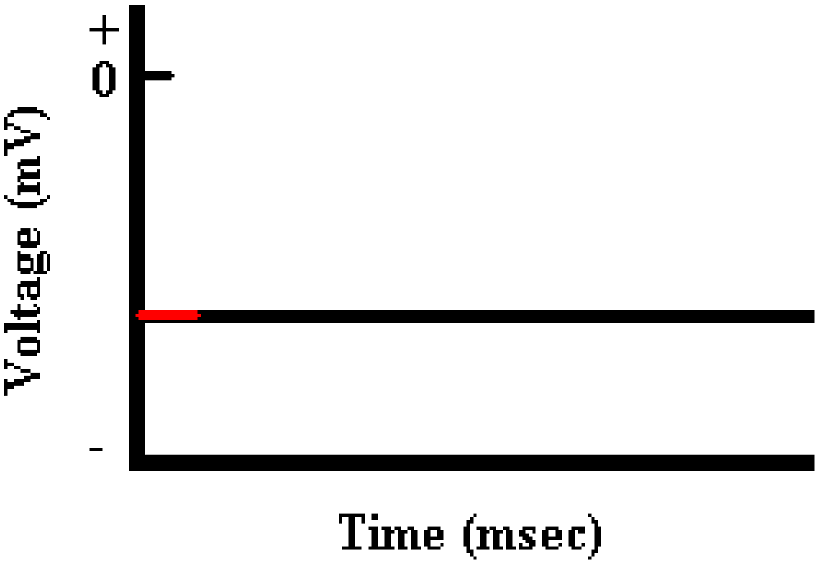
Action potentials: Repolarization

- 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.



Repolarization





THANKS