Cell

Transport of substances through the cell membrane by

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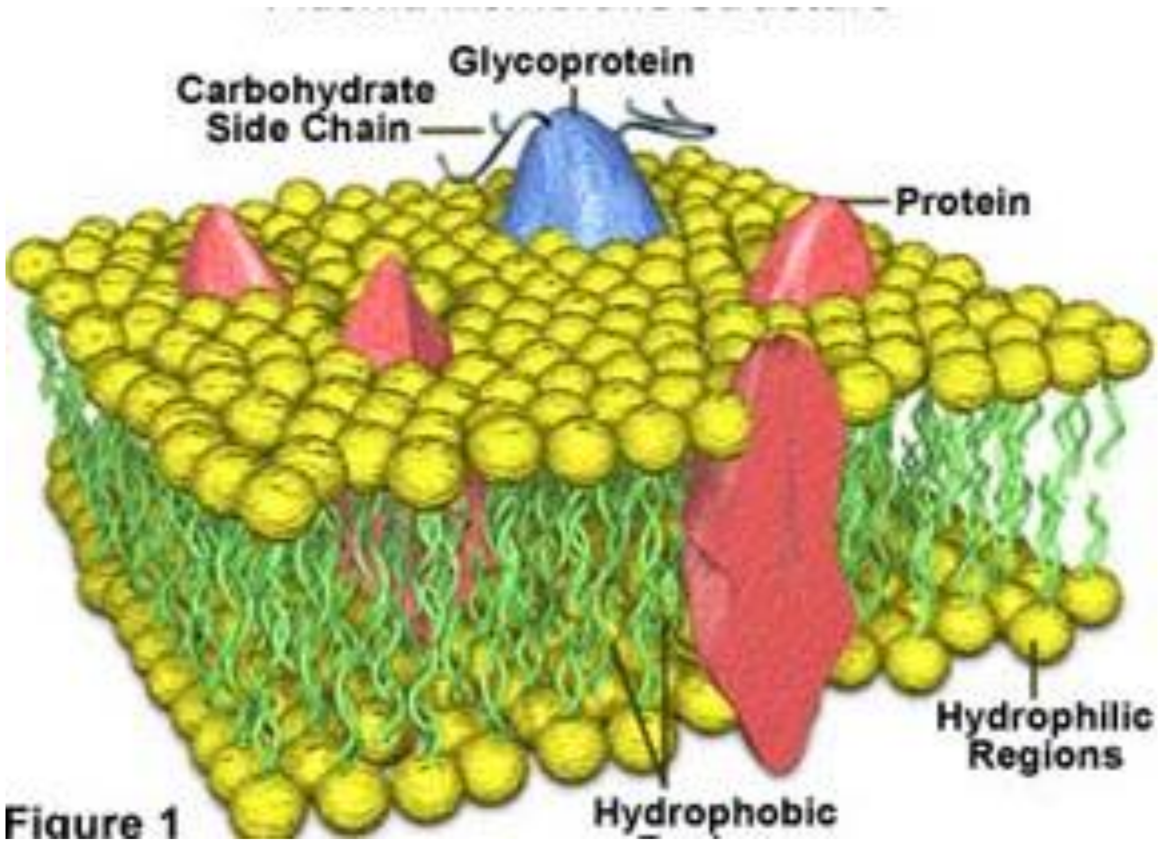
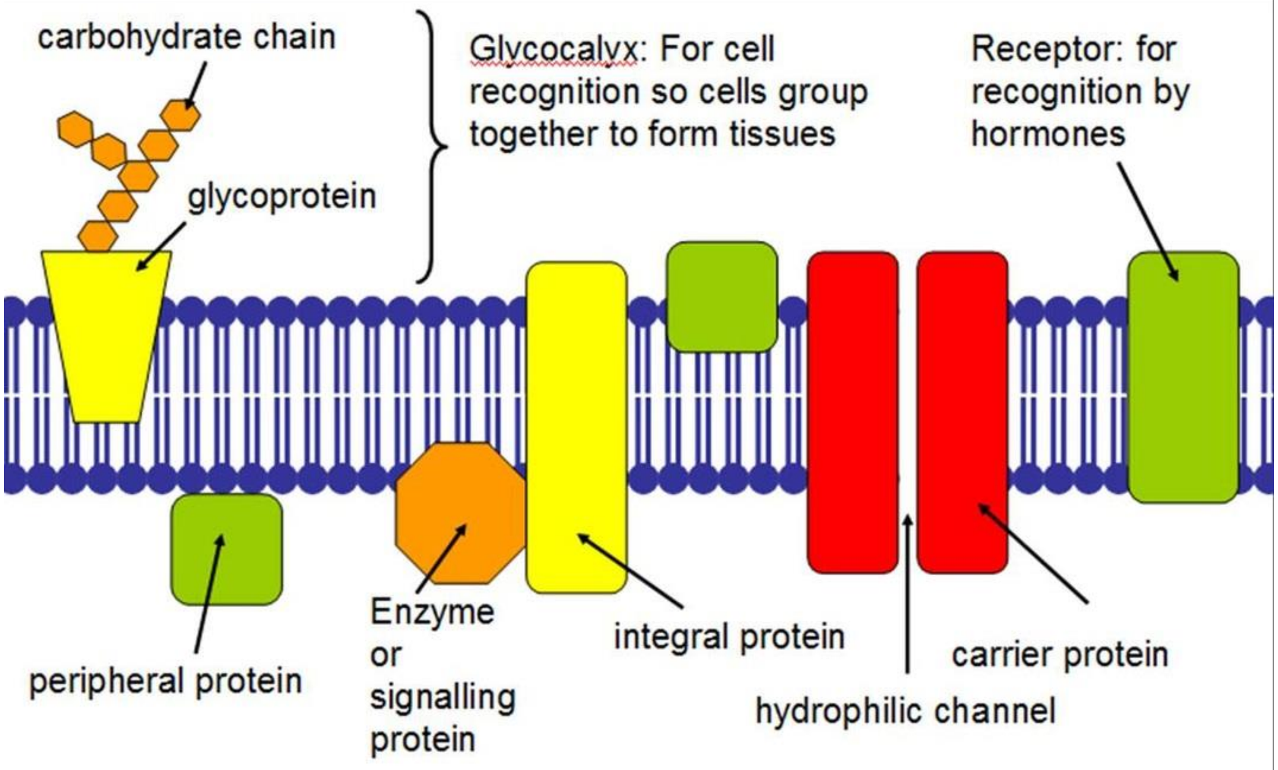


Figure 1

- The membrane consists almost entirely of a lipid bilayer but it also contains large numbers of protein molecules in the lipid many of which penetrates all the way through the membrane.
- The Penetrating proteins can function as transport proteins

The membrane contains many types of protein:



DIFFERENCE BETWEEN

- Channel proteins have watery spaces all the way though the molecule allow the free movement of water and selected ions or molecule
- Channel are highly selective in the types of molecules or ions that are allowed to cross the membrane.
- It allows only those particles whose size is less than 0.8nm.
- Fixed shape
- Depending upon that they attract or repel particular ion.

- Carrier proteins binds to the transported molecule conformational changes, in the proteins molecule then move the substances to the other side of the membrane.
- Carrier proteins are highly selective in the types of molecules or ions that are allowed to cross the membrane.
- It transport substances which has size more than0.8 nm.
- It transport the solute in either direction down the concentration gradient with its change of shape.

Protein channels They are permeable to certain selective substances.
Many of the channels can be opened or closed by gates

- Carrier protein—example is plasma membrane of thyroid gland cells have carrier for iodine.
- Na- K pump is an example of carrier protein.
- Facilitated diffusion occurs through carrier proteins.

- Channel protein- simple diffusion occurs through Channel proteins Channels are named after the ions diffusing through these channels like sodium channels, potassium channels etc
- **Cystic fibrosis** is the disease in which there is defect in Channel proteins, which should be present in all surface membrane of certain cells including those lining the lungs. If channel protein is not correctly positioned in the membrane or if it does not open the chloride ions cannot move out.

Transport mechanism

1. Passive transport (diffusion) which is further subdivided into Simple diffusion and facilitated diffusion.

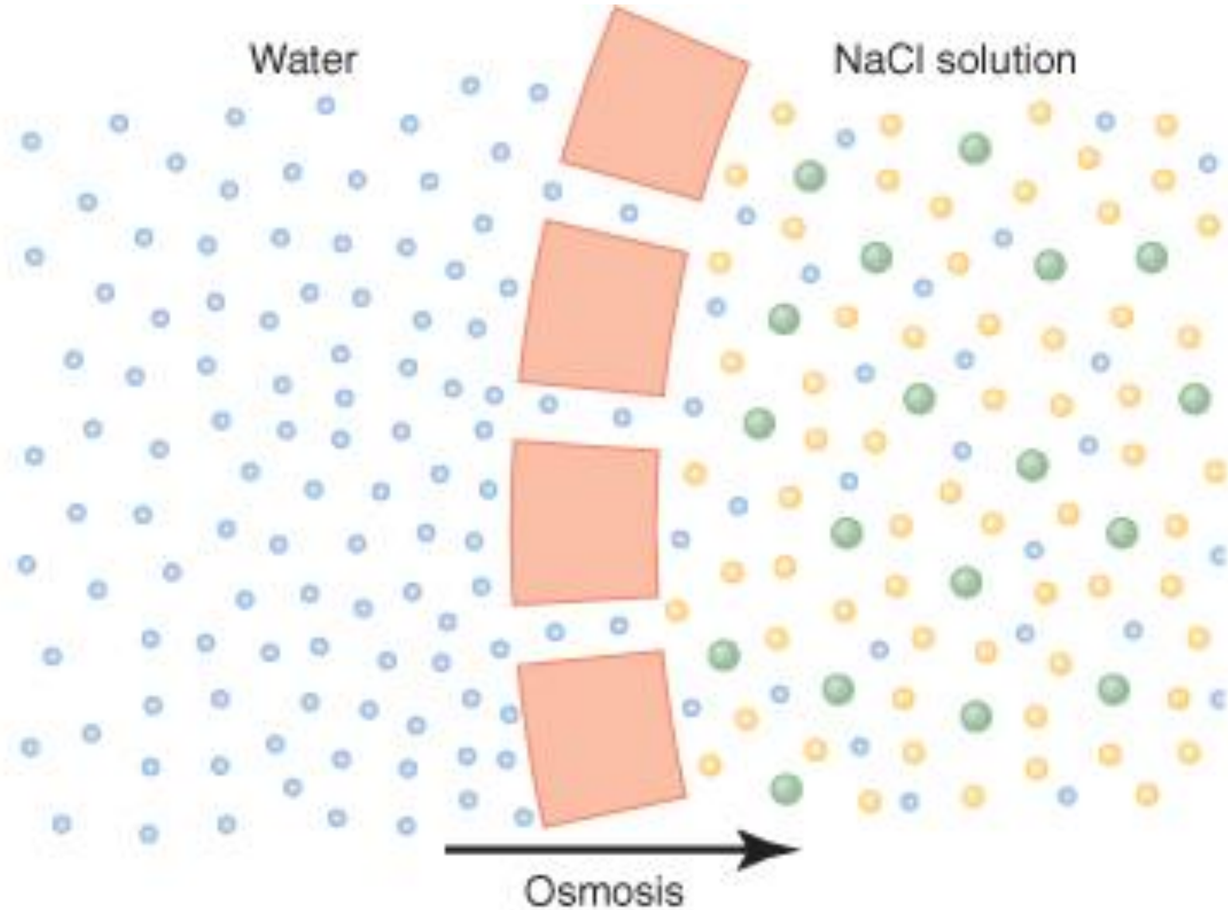
2. Active transport is divided into Primary and secondary the secondary is divided into Sodium co transport mechanism and sodium counter transport mechanism.

3. The third type of transport is transport of large particles by pinocytosis and phagocytosis.

TYPES OF MOVEMENT ACROSS CELL MEMBRANE OF MOLECULES

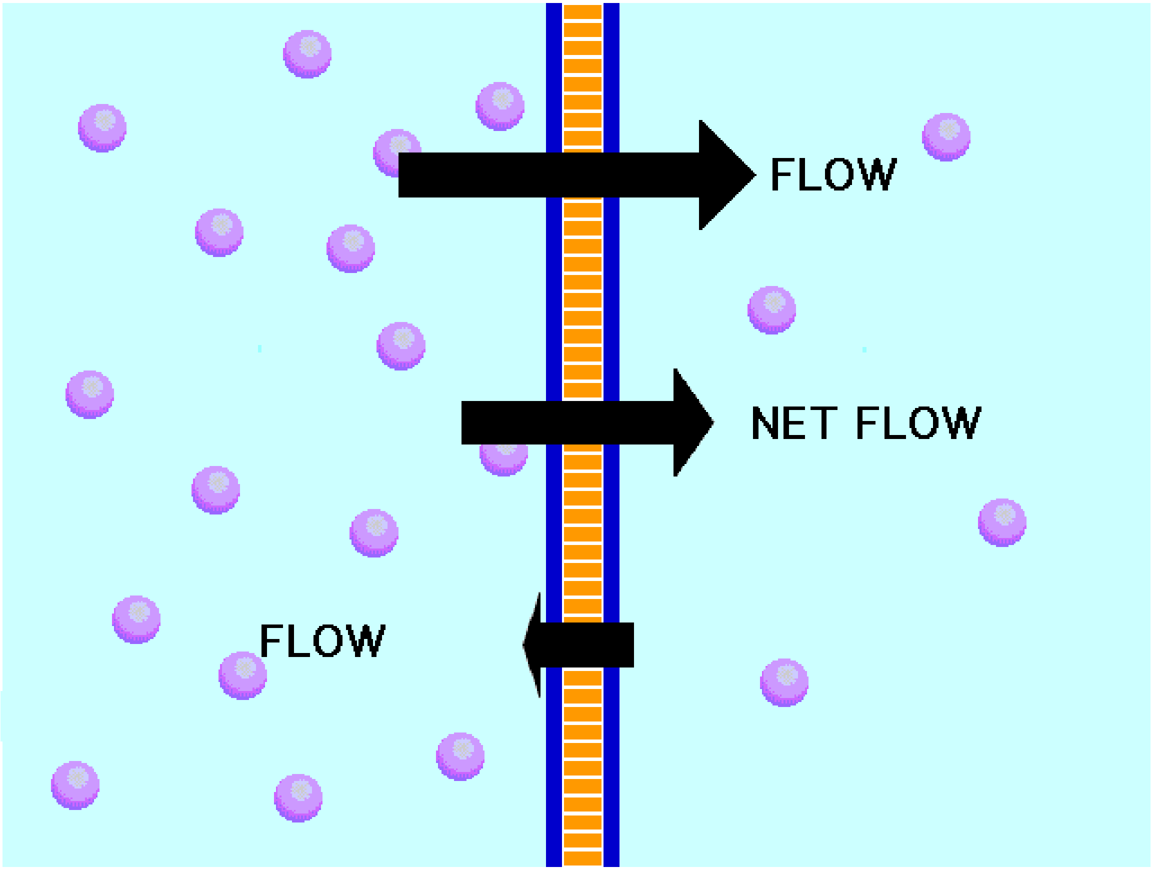
- Passive transport is the transport of substance along the electro chemical gradient .It occurs by diffusion of molecules and does not require energy.
- It is dependent on the permeability of the cell membrane.
- There are three main kinds of passive transport-

  Diffusion, Osmosis and Facilitated Diffusion.


Water
NaCl solution
Osmosis

DIFFUSION

The movement of molecules from a region of high concentration to a region of lower concentration



TYPE OF DIFFUSION

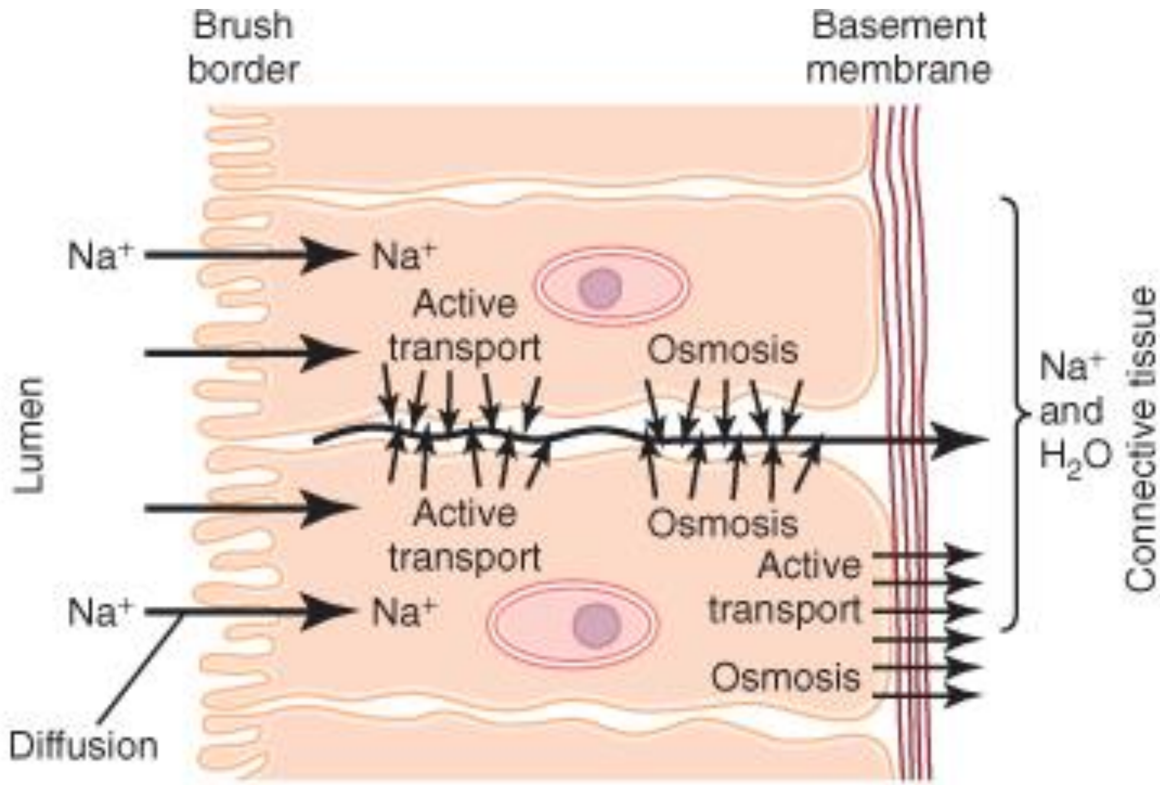
- Diffusion is divided into two subtypes called simple diffusion and facilitated diffusion.
- simple means that kinetic movement of molecules or ions occurs through a membrane opening or through intermolecular spaces without any interaction with carrier proteins in the membrane .The substances like oxygen, carbon dioxide,nitrogen and alcohol are transported through the lipid layer by simple diffusion
- Rate of diffusion is determined by the amount of substance available,
- Velocity of kinetic motion .
- The number and solubility of the substances in lipids
- Size of opening in the membrane.
- Occurs from higher to lower concentration.

Why the water pass through lipid bilayer as it is not lipid soluble

- It passes through lipid bilayer because of its small molecular size and high kinetic energy. Water passes like a bullet through the lipid bilayer before hydrophobic character of lipid can stop them.

ACTIVE TRANSPORT

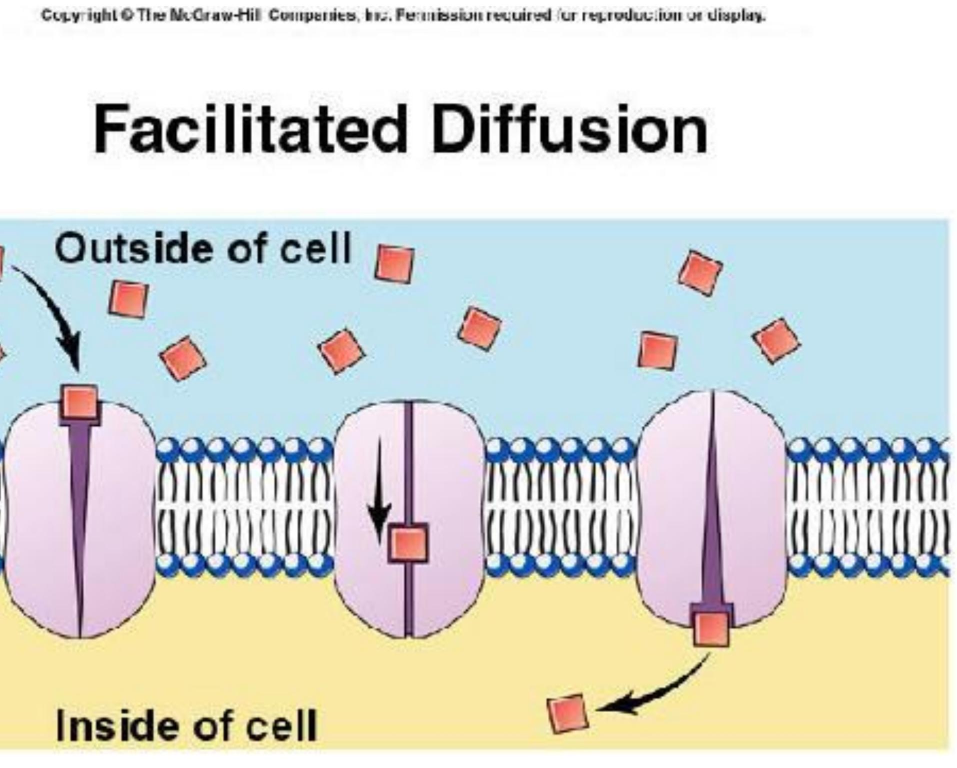
- Movement of ions or other substances across the membranes in combination with a carrier protein.
- Carrier proteins causes the substance to move against an energy gradient,such as from a low concentration state to a high concentration.
- For the movement besides kinetic energy additional source of energy is required.

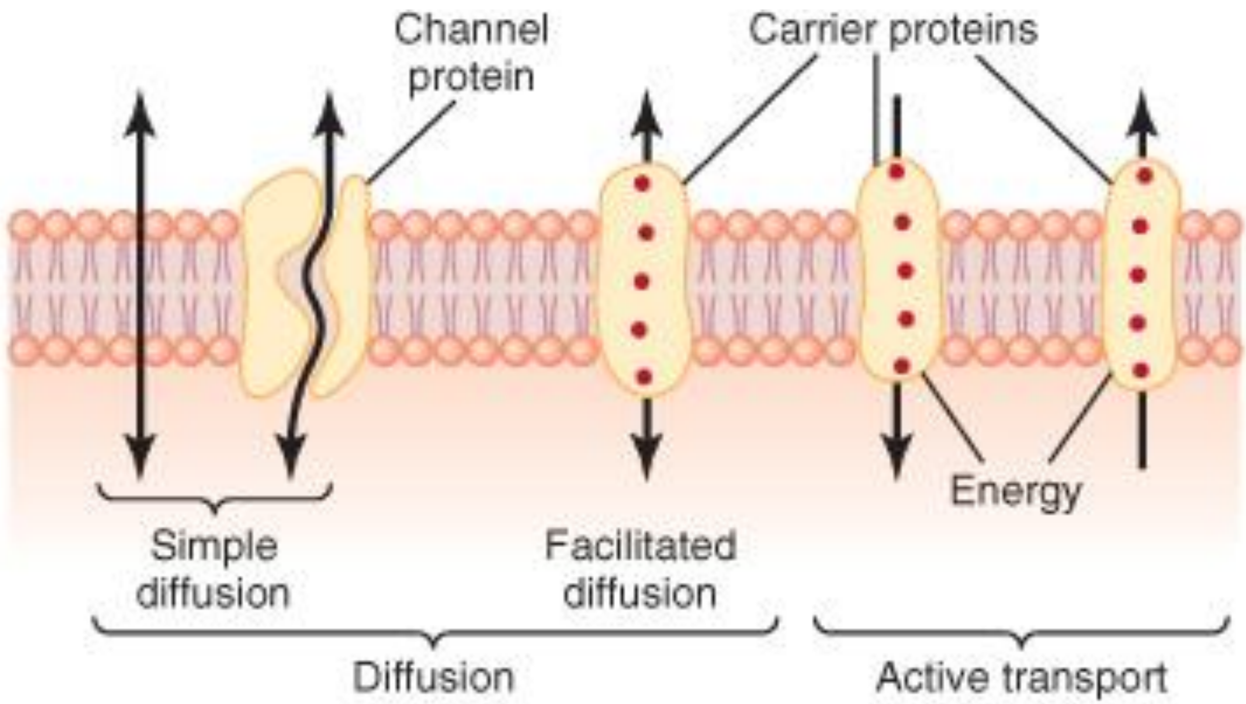

Brush
border
Basement
membrane
Na+
Na+
Active
transport
Osmosis
Lumen
Na+
and
H2O
Connective tissue
Active
transport
Osmosis
Active
transport
Na+
Na+
Osmosis
Diffusion

FACILITATED DIFFUSION

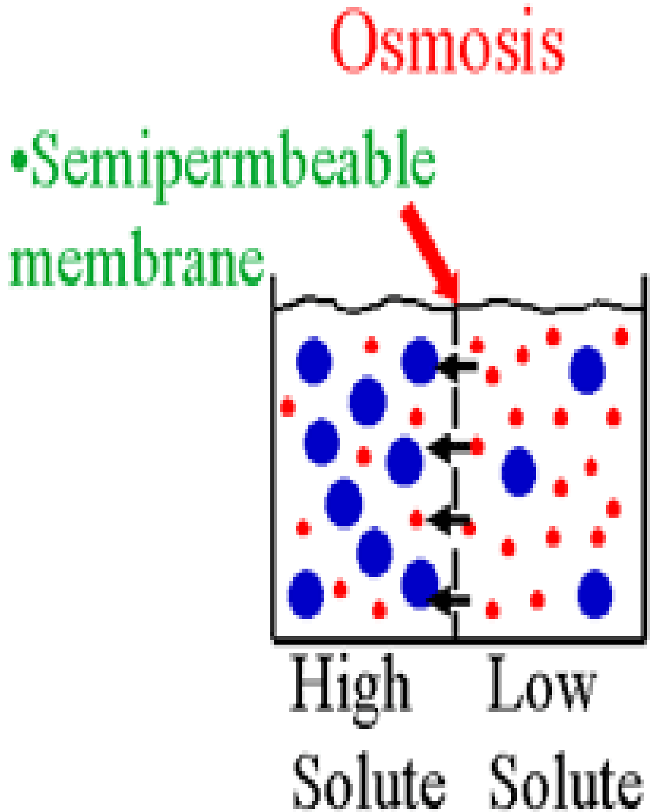
This process does not require ATP but requires cell membrane proteins which are called carrier proteins to carry the molecules across the cell membrane from an area of higher concentration to an area of lower concentration.

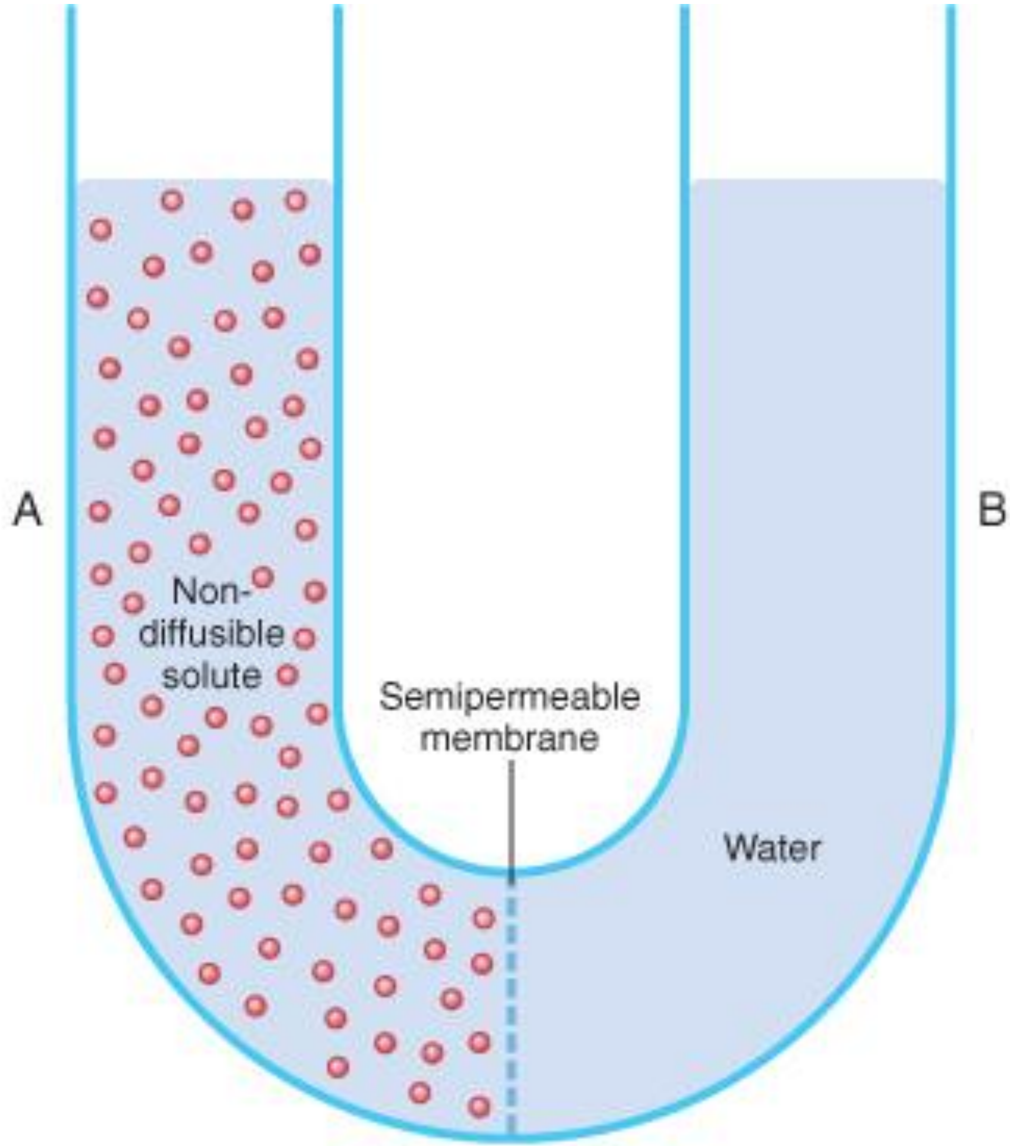
Glucose and amino acids are transported by facilitated diffusion.




Channel
protein
Carrier proteins
Energy
Simple
diffusion
Facilitated
diffusion
Diffusion
Active transport

The movement of water across a semi permeable membrane. Osmosis is the movement of water (red dots) through a semi permeable membrane to a higher concentration of solutes (blue dots).




A
B
Non-
diffusible
solute
Semipermeable
membrane
Water

Why ions though of smaller size cannot diffuse through lipid bilayer

- Ions cannot diffuse through lipid bilayer because of the presence of electric charge.
- Electric charge impedes the passage in two ways
- Electric charge of ion causes multiple water molecules to become bounded with the ion to form hydrated ion. This increases the size of the ion.
- Each half of the lipid bilayer is formed of polar lipids having either negative or positive charges. By these both negatively as well as positively charged ions are repelled.

SELECTIVE PERMEABILITY OF PROTEIN CHANNELS

- Throughout the central lipid layer of the cell membrane, there are some pores.
- The integral protein molecules of protein layer invaginate into these pores from either surface of the cell membrane.The pores are called the hypothetical pores.
- The pores form the channels for the diffusion of water, electrolytes and other substances, which cannot pass through the lipid layer.
- Selective permeability is the characteristic feature of protein channels.

SELECTIVE PERMEABILITY OF PROTEIN CHANNELS

- Selective permeability depends on **diameter**, **shape, nature of the electrical charges** and **chemical bonds** along its inside surfaces
- *Sodium channel,* is 0.3 by 0.5 nanometer in diameter, but more important, the inner surfaces of this channels are strongly negative charged.
- Strong negative charges can pull small dehydrated sodium ions into these channels, actually pulling the sodium ions away from their hydrating water molecules.
- Sodium ions diffuse in either direction according to the usual laws of diffusion.

POTASSIUM CHANNELS

- Are slightly **smaller** then sodium channels, only 0.3by 0.3 nanometer, **not negatively charged** and their chemical bonds are different.
- No strong attractive force is pulling ions into the channels, and the potassium ions are not pulled away from the water molecules that hydrate them.
- The hydrated potassium is smaller then hydrated sodium because sodium ions attracts more water molecules.
- Smaller hydrated potassium ions can pass easily through this small channel, larger hydrated sodium ions are rejected, thus selective the permeability for a specific ion.

REGULATION OF THE CHANNELS, AND GATED CHANNELS CATEGORIZATION

- Protein channels are continuously opened(un gated) and most channels are always closed (gated)The gated channels are opened when required. They are categorized as
- Voltage gated channels.
- Ligand gated channels.
- Mechanically gated channels

VOLTAGE GATED CHANNELS

- Open whenever there is a change in the electrical potential.
- Example is, in **neuromuscular junction** when action potential reaches axon terminal, the calcium channels are opened and calcium ions diffuse into the interior of the axon terminal from extracellular fluid in large number.

LIGAND GATED CHANNELS

- Open in the presence of some hormonal substance. The hormone substances are called ligands and the channels are called ligand gated channels.
- Best example of ligand gated channels is release of acetylcholine through the axon terminal and reach the synaptic cleft

MECHANICAL GATED CHANNELS

- Opened by some mechanical factors.
- Example are receptor cells(hair cells) for hearing. The sound wave cause the movement of hairs of the receptors in the ear. The movement of the hairs cause opening of ionic channels leading to the developing of receptor potential.

FACILITATED DIFFUSION (CARRIER MEDIATED)

- Water soluble substances having larger molecules cannot diffuse through the protein channels.
- Such substances pass through the cell membrane with the help of some carrier proteins.
- By this process, the substances are transported across the cell membrane faster then the transport by simple diffusion.

Describe the mechanism of Facilitated diffusion

- Carrier protein causing facilitated diffusion has a receptor site for binding with a specific substances.
- Molecules of a specific substances binds with the receptor site.
- Then within a fraction of a second conformational changes occurs in a carrier protein and causes channel to open on the opposite side of the membrane (to close on the side which was open before filling the receptor site)
- Because of the weak binding force between the molecules and the receptor site, molecule breaks away from the site and diffuses to the opposite site.

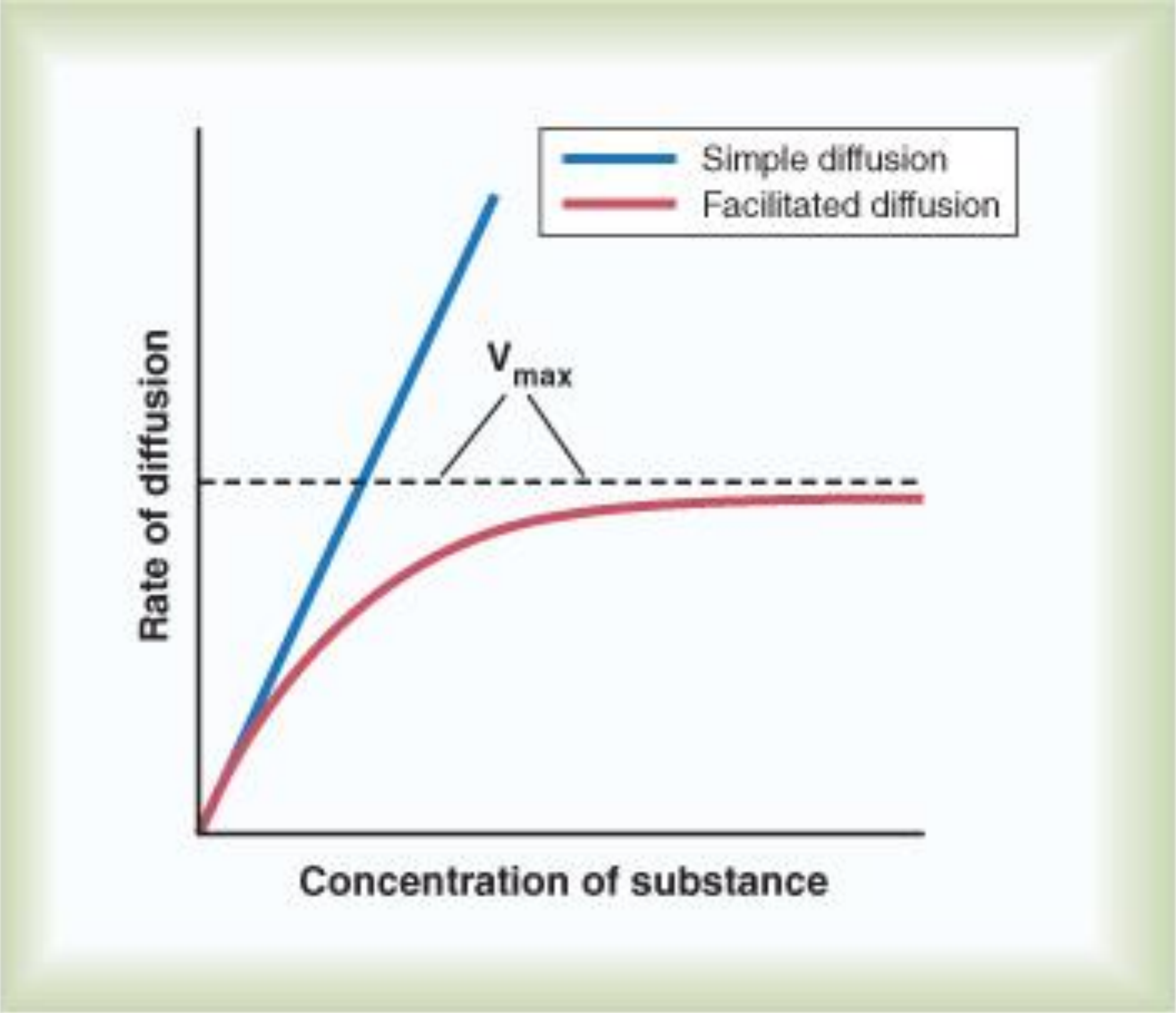
FACILITATED DIFFUSION

- In facilitated diffusion as the concentration of the diffusing substance increases the rate of diffusion approaches a maximum and this is called Vmax.

VMAX (FACILITATED DIFFUSION MAXIMUM RATE)

Examples are transport of glucose and amino acids across the cell membrane.

- A carrier is specific only for a substance or group of substances of similar kind e.g, the carrier molecule for glucose is a protein of molecular weight of 45000 and it can also transport several other monosaccharides that have structures similar to glucose e.g galactose.
- If the carrier is common for two or more substances, these substances compete for the carrier receptor site,inhibit the rate of transport of the other substances.


Simple diffusion
Facilitated diffusion
Rate of diffusion
V_{max}
Concentration of substance

FACTORS AFFECTING RATE OF DIFFUSION

- **Permeability of the cell membrane** is directly proportional to the rate of diffusion.
- Rate of diffusion is directly proportional to the body **temperature**.
- Rate of diffusion is directly proportional to the **concentration gradient of the diffusing substance across the cell membrane**.
- Diffusion is directly proportional to the **solubility of substances**, particularly the lipid soluble substances.

FACTORS AFFECTING RATE OF DIFFUSION

- Rate of diffusion is inversely proportional to the **thickness of the cell membrane**.
- Rate of diffusion is inversely proportional to the **size of molecules.**
- Rate of diffusion is inversely proportional to the **size of the ions.**
- Rate of diffusion is inversely proportional to the **charge of ions**

ACTIVE TRANSPORT

- Movement of substances against the chemical or electrical or electro chemical gradient is called active transport.
- It is like swimming in the opposite direction of water flow in a river.
- It is called up hill transport.
- Active transport requires energy.
- Liberated mostly by break down of high energy compounds like ATP.

CONTINUED ACTIVE TRANSPORT

- Active transport occurs with the help of **carrier protein** as in the case of facilitated diffusion.
- Each carrier protein can only carry one substance (uniports or uniport pumps) or more then one substance (simports or anti ports) across the cell membrane.

MECHANISM OF ACTIVE TRANSPORT

- When a substance to be transported across the cell membranes comes near the cell, it combines with the carrier protein of the cell membrane (substance – protein) complex is formed.
- This complex moves towards the inner surface of the cell membrane.
- Substance is released from the carrier proteins.
- The same carrier proteins moves back to the outer surface of the cell membrane to transport another molecule of the substance.

SUBSTANCES TRANSPORTED BY ACTIVE TRANSPORT

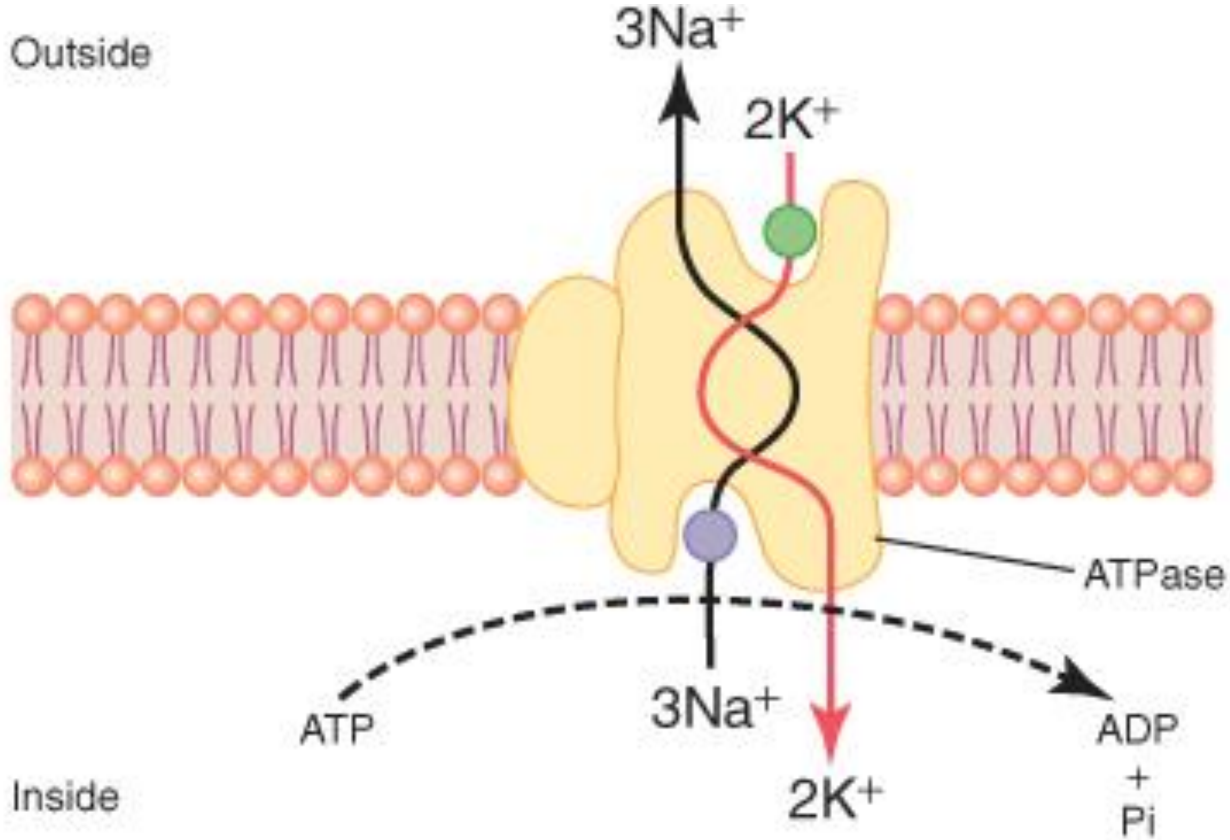
- Substances transported actively are in ionic form that is sodium, potassium, calcium, hydrogen, chloride and iodide.
- Non ionic substances are glucose, amino acids and urea.

TYPES OF ACTIVE TRANSPORT

- The active transport is of two types namely:
- **Primary active transport**
- **Secondary active transport**

PRIMARY ACTIVE TRANSPORT

- Primary active transport: energy is liberated directly from the breakdown of ATP.
- By this method the substances like sodium, potassium, calcium, hydrogen and chloride are transported across the cell membrane.



Outside
3Na+
2K+
ATPase
ATP
3Na+
2K+
ADP
+
Pi
Inside

PRIMARY ACTIVE TRANSPORT OF SODIUM POTASSIUM (SODIUM POTASSIUM PUMP)

- Carrier protein of this pump is made of globular protein with a molecular weight of 100,000.It has the following feature.
- The carrier proteins involved in sodium potassium pump has got six sites which are as follows
- Three receptor sites for binding Na ions on the portion of protein protruding to the interior of the cell
- Two receptor sites for K ions on the outside surface.
- One site for the enzyme adenosine triphosphatase (ATPase) which is near the site of sodium.

MECHANISM OF ACTION OF SODIUM POTASSIUM PUMP

- ATP ase function of the protein is activated.
- ATP split into ADP and high energy phosphate bond. Thus energy is liberated. The energy liberated causes conformational changes in protein carrier molecule. Because of this the outer surface of the molecule with potassium ions now faces the inner side of the cell and the inner surface of the protein molecules with sodium ions faces the outer side of the cell.
- Disassociation and release of ions takes place.
- Sodium ions are released outside and potassium ions are released inside the cell.
- Utilizes 30% of cell energy expenditure.

Importance of Na K pump

- This pump is present in all the cells of the body responsible for the distribution of sodium potassium ions across the cell membrane.
- Development of negative electrical potential inside the cell.
- Help to establish the resting membrane potential.
- It helps in maintaining the cell volume constant.

ELECTROGENIC ACTIVITY OF SODIUM POTASSIUM PUMP

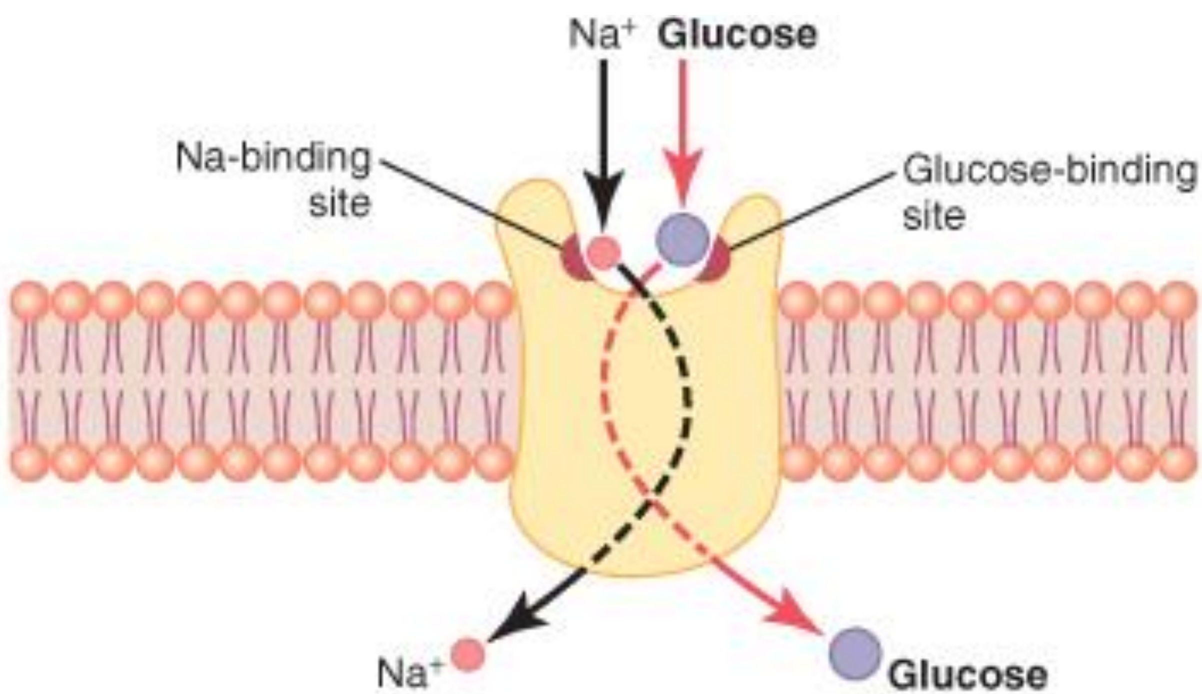
- The pump moves three sodium ions outside the cell and two potassium ions inside the cell.
- When the pump works once there is a net loss of positively charged ion from the cell. Creates -4mv potential
- Continuous activity cause deduction in the number of positively charged ions leading to the development of negative potential inside the cell, this is called electrogenic activity of sodium potassium pump.

TRANSPORT OF CALCIUM IONS

- Calcium is actively transported from inside to outside the cell by another pump called calcium pump.
- Calcium pump is opened by a separate calcium protein.
- The energy is obtained by the breakdown of ATP.
- Calcium pump are present in sarcoplasmic reticulum in the muscle and mitochondria of all the cells.

SECONDARY ACTIVE TRANSPORT

- Transport of substance with sodium ions by means of a common carrier protein is called the secondary active transport.
- Secondary active transport is of two types: namely **sodium co transport** and **sodium counter transport**.
- Separate carrier proteins operates for each type.
- Protein that transport two different molecules in the same direction across the cell membrane is called **simport** or **simport pump**.
- The carrier protein that transports two different ions or molecules in opposite direction across the cell membrane is called **antiport** or **antiport pump.**


Na+ Glucose
Na-binding site
Glucose-binding site
Na+
Glucose

SODIUM CO TRANSPORT

- Along with sodium and the substance to be transported move in the same direction ,carried by carrier protein called symport.
- Energy is obtained from the diffusion process of sodium due to concentration gradient across the cell membrane.
- Glucose, amino acids, chlorides, iodide, urates and iron are carried by sodium co transport.

SODIUM CO TRANSPORT OF GLUCOSE

- One sodium ion and one glucose molecule from the extracellular fluid bind with the respective receptor sites of carrier protein of the cell membrane.
- Carrier protein is activated.
- Conformational changes in the carrier proteins occur.
- Sodium and glucose are released into the cell i.e. absorption of glucose from intestines and renal tubules.

SODIUM CO TRANSPORT OF AMINO ACIDS

- For the transport of amino acids there are five sets of carrier proteins in the cell membrane.
- Each one carries different amino acids depending upon the molecular weight of the amino acids.
- Examples: absorbtion of amino acids from intestines and renal tubules.

SODIUM COUNTER TRANSPORT

- Sodium is transported in one direction and the substance is transported in opposite direction, by the carrier proteins called antiport.
- Na ions move to the interior of the cell and the other substance or ion move to the exterior against the electrochemical gradient.

SODIUM CALCIUM COUNTER TRANSPORT

- In this sodium and calcium ions move in opposite direction with the help of a carrier proteins.It is present in all the cells.
- Na-H counter transport especially occurs in proximal tubular cells of the kidneys.

MEMBRANE POTENTIAL AND ACTION POTENTIAL

- Potassium and Sodium Channels

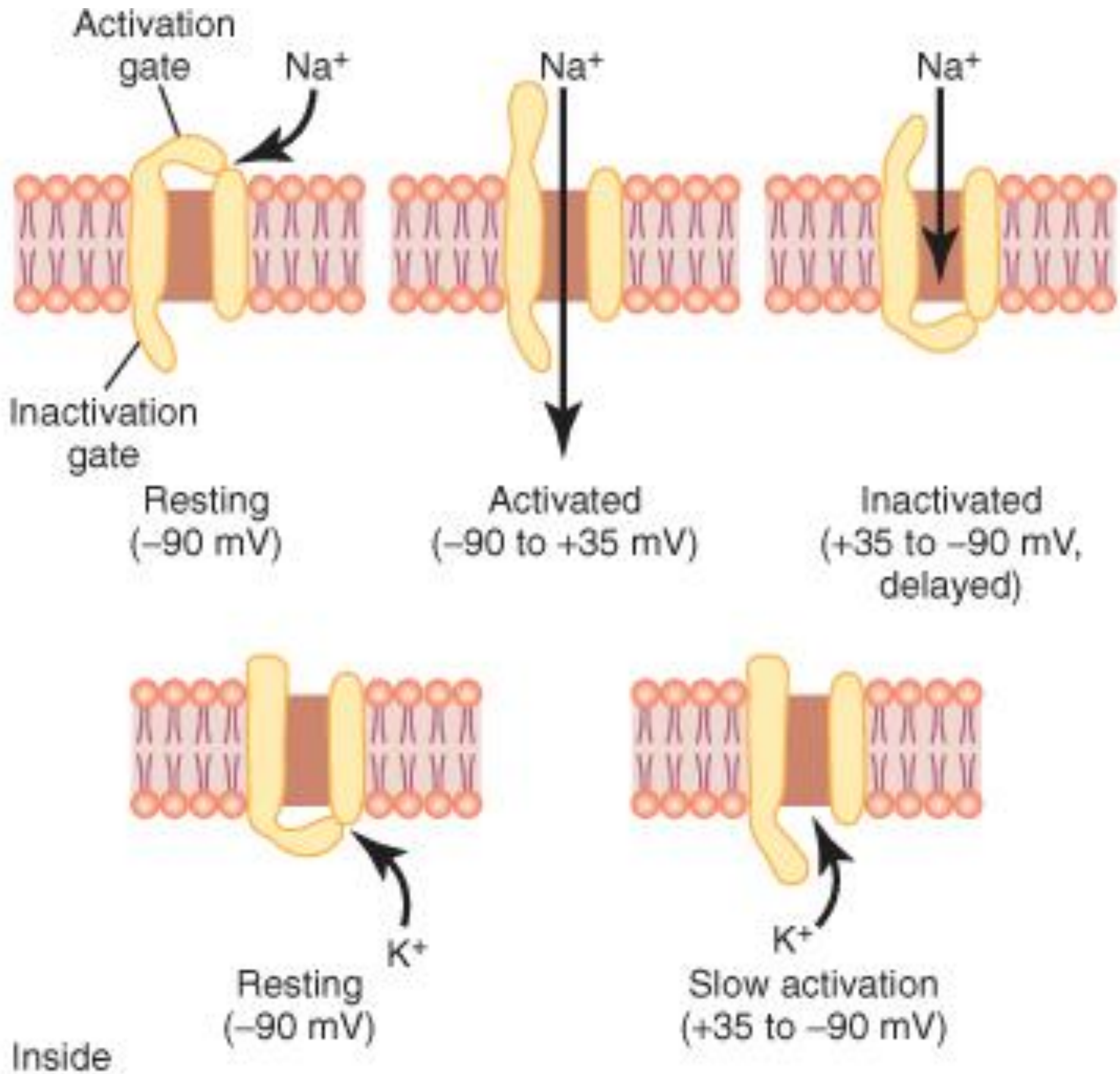
There are channel proteins in the cell membrane through which potassium and sodium can normally leak towards concentration gradient. They are 100 times more permeable to

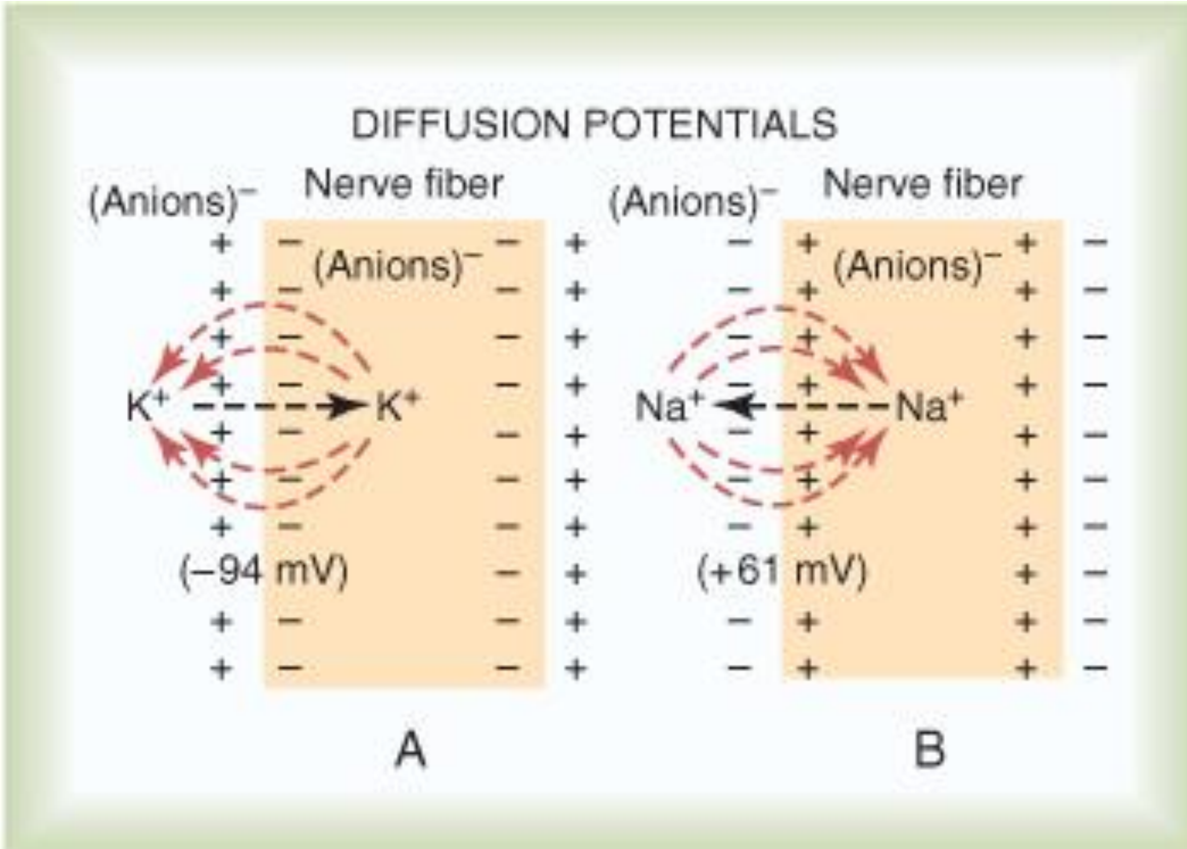
potassium then sodium responsible for resting membrane potential.

As the membrane is 50-70 times more permeable to K,it continuously moves out, creating negativity inside with -86mv potenial.

VOLTAGE GATED SODIUM CHANNELS

- Has two gates
- Activated gate: On **outside, remains closed** at normal resting potential (_90mv).Activated or opened when membrane potential becomes less negative between-70 and-50.So sodium ions influx to cause depolarization.
- Inactivation gate: On **inside, remains opened** at normal RMP(-90mv).Inactivated or closed when membrane potential becomes +35mv.So,sodium ions influx is blocked.

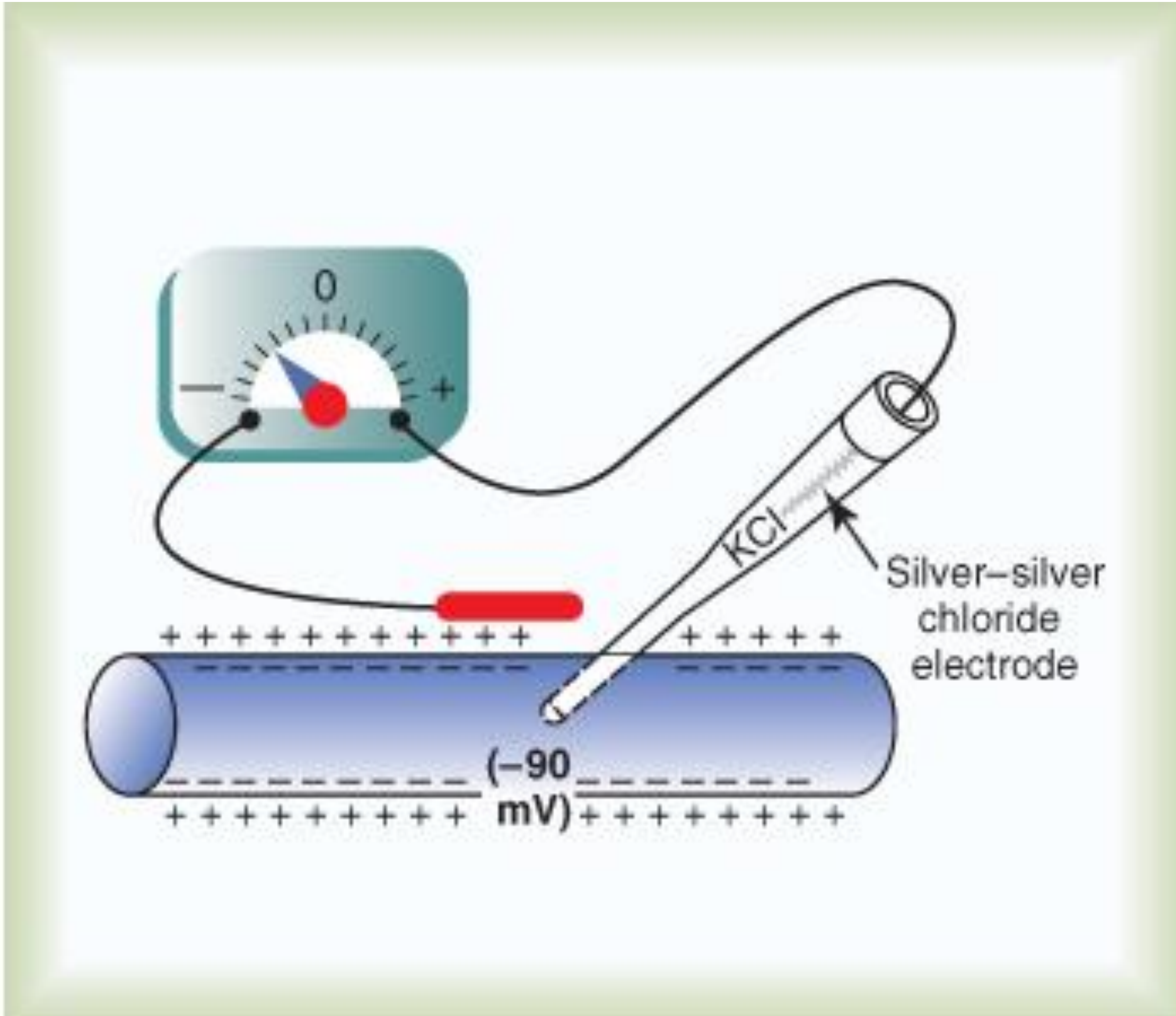

Activation gate
Na+
Na+
Na+
Inactivation gate
Resting
(−90 mV)
Activated
(−90 to +35 mV)
Inactivated
(+35 to −90 mV, delayed)
K+
Resting
(−90 mV)
K+
Slow activation
(+35 to −90 mV)
Inside


DIFFUSION POTENTIALS
(Anions)⁻
Nerve fiber
(Anions)⁻
K⁺
K⁺
(−94 mV)
A
(Anions)⁻
Nerve fiber
(Anions)⁻
Na⁺
Na⁺
(+61 mV)
B

	EXTRACELLULAR FLUID	INTRACELLULAR FLUID
Na^+	142 mEq/L	10 mEq/L
K^+	4 mEq/L	140 mEq/L
Ca^{++}	2.4 mEq/L	0.0001 mEq/L
Mg^{++}	1.2 mEq/L	58 mEq/L
Cl^-	103 mEq/L	4 mEq/L
HCO_3^-	28 mEq/L	10 mEq/L
Phosphates	4 mEq/L	75 mEq/L
$SO_4^{=}$	1 mEq/L	2 mEq/L
Glucose	90 mg/dl	0 to 20 mg/dl
Amino acids	30 mg/dl	200 mg/dl ?
Cholesterol, Phospholipids, Neutral fat	0.5 g/dl	2 to 95 g/dl
PO_2	35 mm Hg	20 mm Hg ?
PCO_2	46 mm Hg	50 mm Hg ?
pH	7.4	7.0
Proteins	2 g/dl (5 mEq/L)	16 g/dl (40 mEq/L)

MEMBRANE POTENTIAL

- Electrical potential across cell membrane is called membrane potential.
- Under resting condition, outside is positive and inside is negative
- During activity or action potential, outside becomes negative and inside is positive.


0
–
+
KCl
Silver–silver chloride electrode
(–90 mV)

RESTING MEMBRANE POTENTIAL

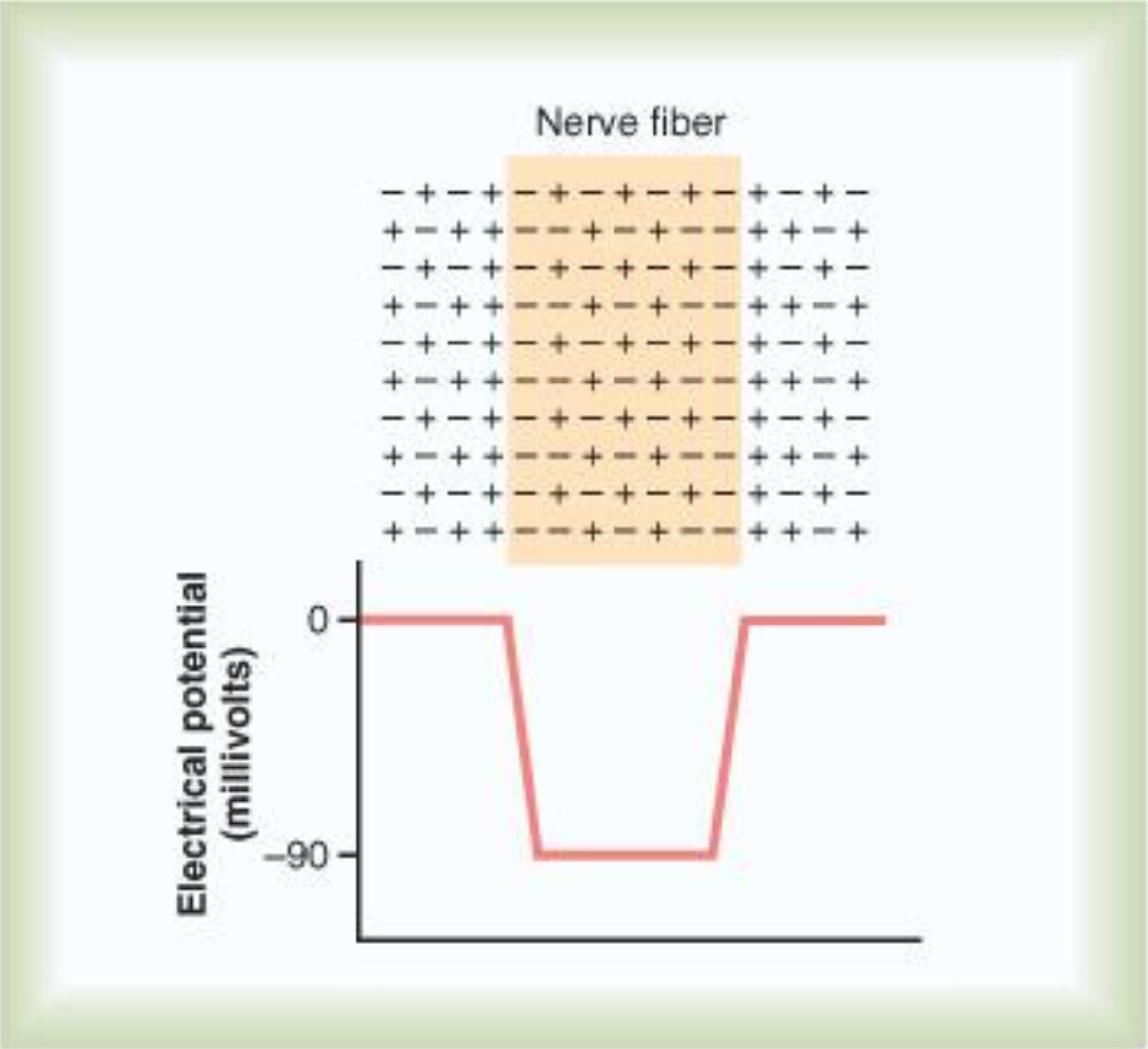
- Membrane potential of nerve fiber when it is

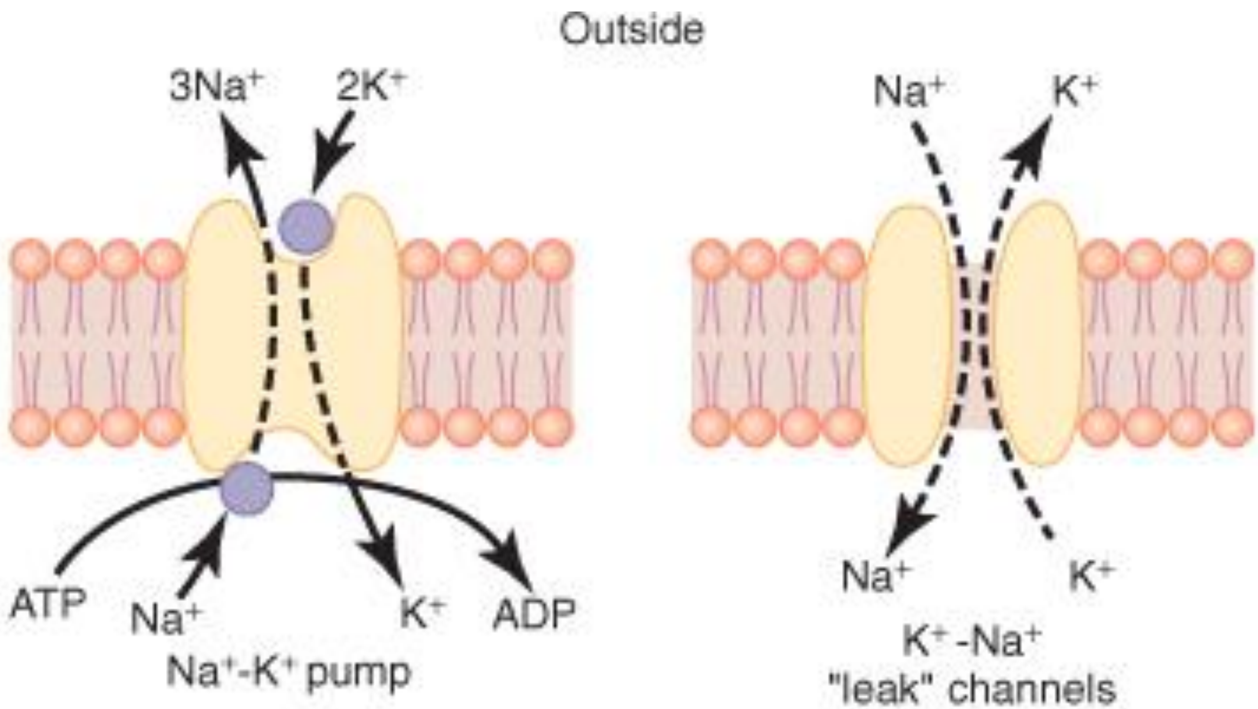
not transmitting signals or in resting condition, is called resting membrane potential.

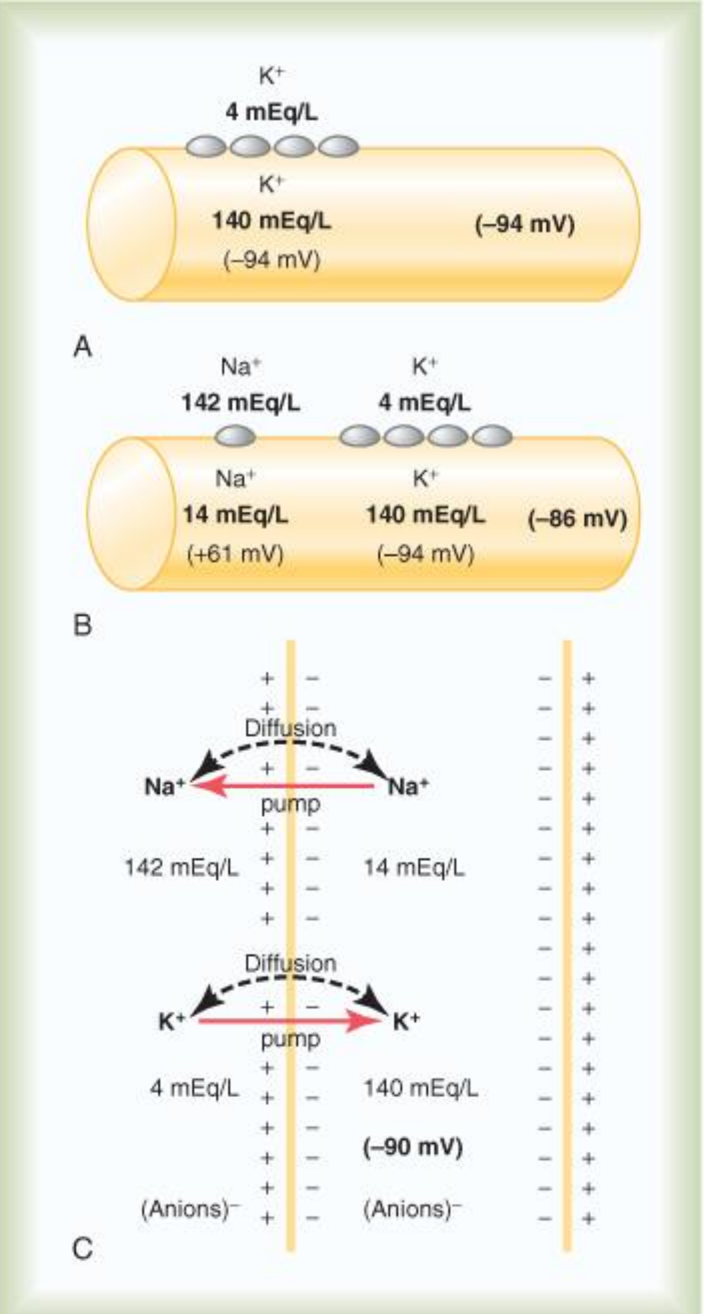
Value: _90mV on inside.

RESTING MEMBRANE POTENTIAL(RMP)

- Membrane potential of nerve fiber when it is not transmitting signal or in resting condition, is called RMP.
- Value: -90mV on inside.
- Contribution by K+ diffusion potential is that K+ concentration inside is 140mEq/L and outside is 4mEq/L so,K+ diffuses through K+ Na+ leak channels to outside until membrane potential becomes -94mV inside.
- As K has a positive charge its movement will cause positivity outside and negativity inside.
- This movement of K inside will continue until inside become sufficiently positive to repel it.At this point the net movement of K will stop.
- -94mV prevents further out flux of K+,hence called Nernst potential for K.


Nerve fiber
Electrical potential (millivolts)
0
−90


Outside
3Na+
2K+
Na+
K+
ATP
Na+
K+
ADP
Na+-K+ pump
Na+
K+
K+-Na+
"leak" channels



K+
4 mEq/L
K+
140 mEq/L
(–94 mV)
(–94 mV)
A
Na+
142 mEq/L
K+
4 mEq/L
Na+
14 mEq/L
(+61 mV)
K+
140 mEq/L
(–94 mV)
(–86 mV)
B
Diffusion
Na+
Na+
pump
142 mEq/L
14 mEq/L
Diffusion
K+
K+
pump
4 mEq/L
140 mEq/L
(–90 mV)
(Anions)−
(Anions)−
C

CONTRIBUTION BY Na+ DIFFUSION POTENTIAL

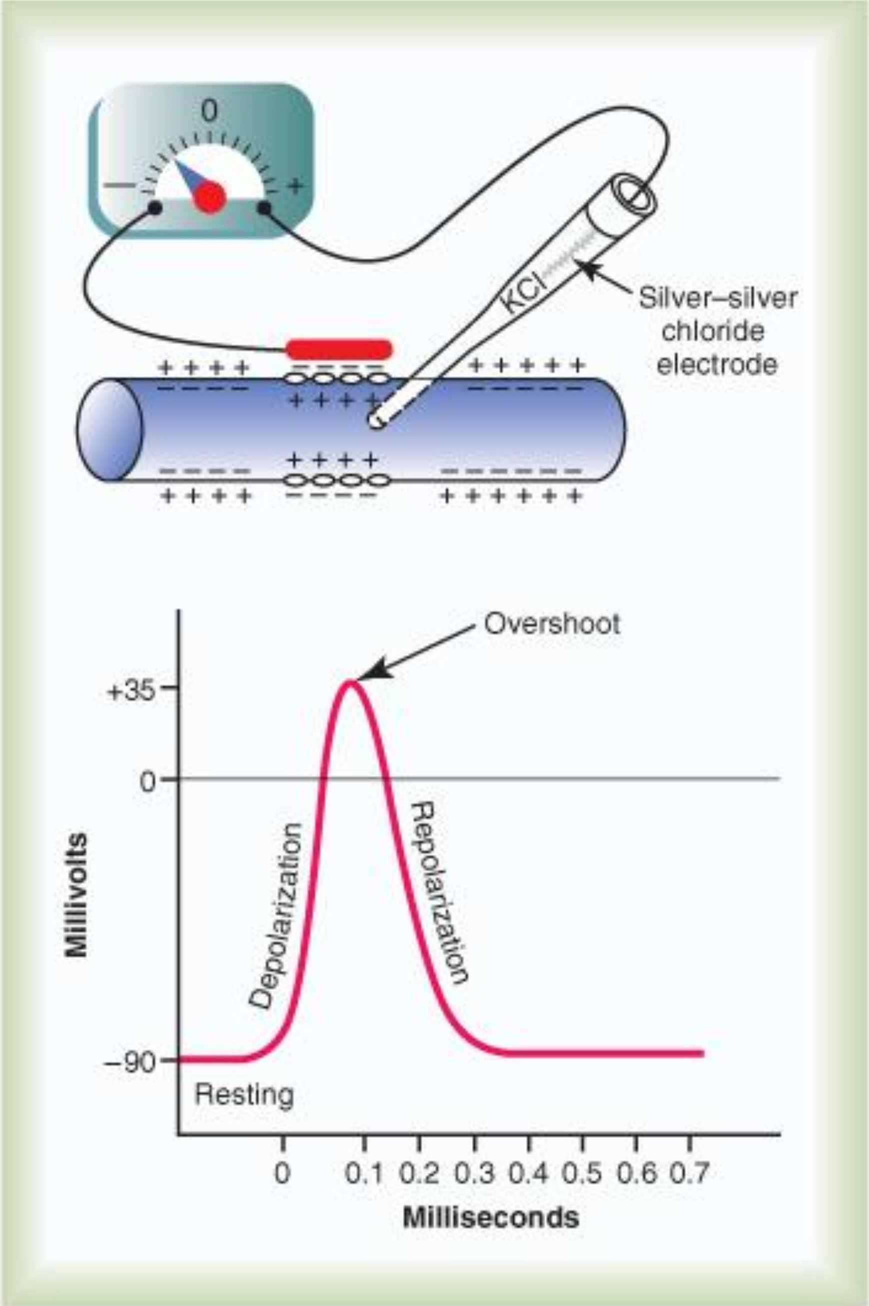
- Na+ concentration outside is 142 mEq/L and inside is 10 mEq/L so Na+ diffuses through **K+, Na+ leak channels** to inside until membrane, potential becomes +61 mV inside, which prevents further influx of Na+, hence called Nernst potential for Na+.
- K+ Na+ leak channels is 100 times less permeable to Na+ then K+.
- Na+ K+ electrogenic pump transports 3 Na+ ions to exterior while 2 K+ ions to interior, thereby creating negativity inside cell membrane. It contributes-4mV to resting membrane potential.

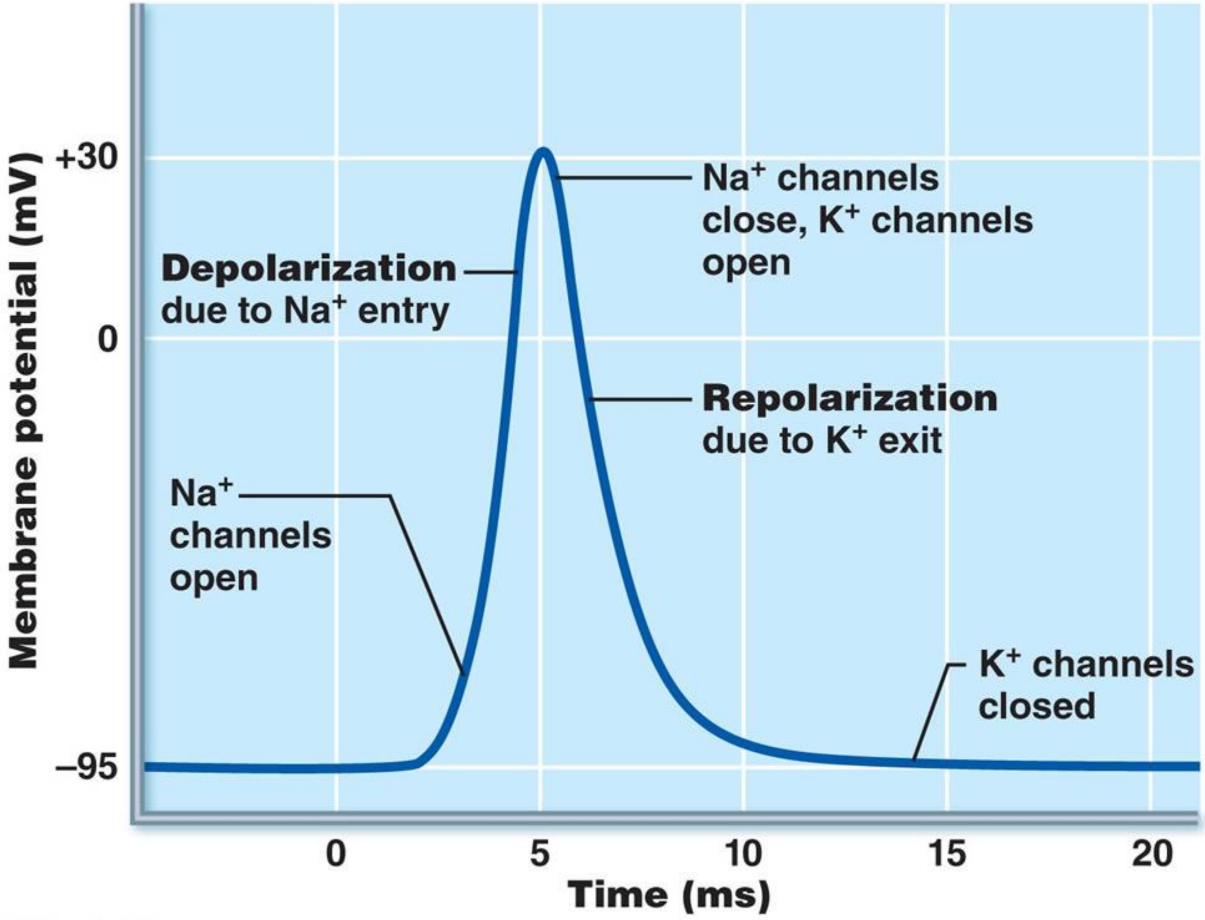
NERNST POTENTIAL

- Potential difference across cell membrane that can block further diffusion of an ion completely towards concentration gradient is called Nernst potential of that ion.

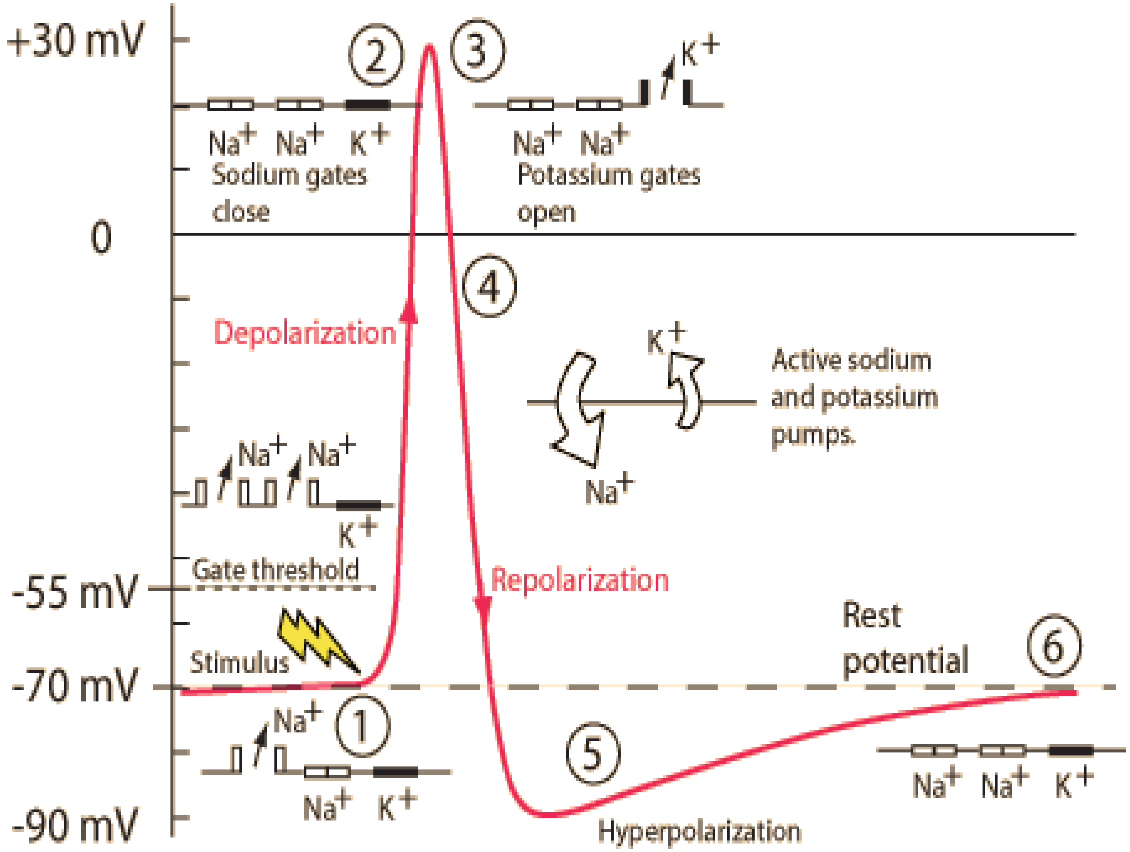
ACTION POTENTIAL

- Transport of ions across cell membrane, due to stimulus to change membrane potential from normal negative value to positive and then back to negative value, giving rise to an impulse, is called Action potential. OR
- Changes in membrane potential that occurs during activity are collectively called action potential.


0
—
+
KCl
Silver–silver chloride electrode
Overshoot
+35
0
−90
Millivolts
Depolarization
Repolarization
Resting
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7
Milliseconds



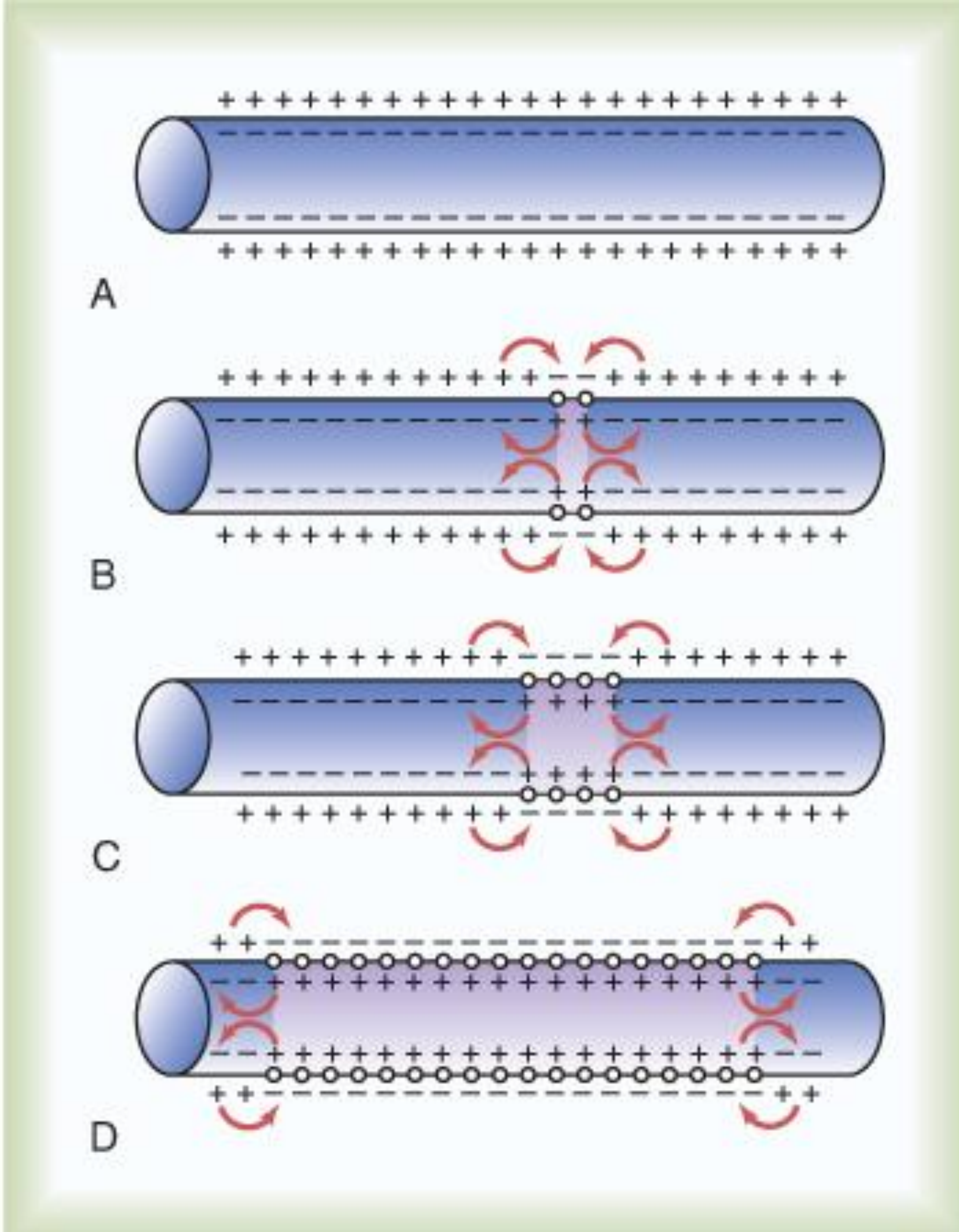
Membrane potential (mV)
+30
0
–95
Depolarization
due to Na+ entry
Na+ channels
close, K+ channels
open
Repolarization
due to K+ exit
Na+
channels
open
K+ channels
closed
0
5
10
15
20
Time (ms)



+30 mV
0
-55 mV
-70 mV
-90 mV
2
3
Na+ Na+ K+
Sodium gates close
Na+ Na+
K+
Potassium gates open
4
Depolarization
K+
Active sodium and potassium pumps.
Na+
Na+ Na+
K+
Gate threshold
Repolarization
Rest potential
6
Stimulus
Na+
1
Na+ K+
5
Na+ Na+ K+
Hyperpolarization

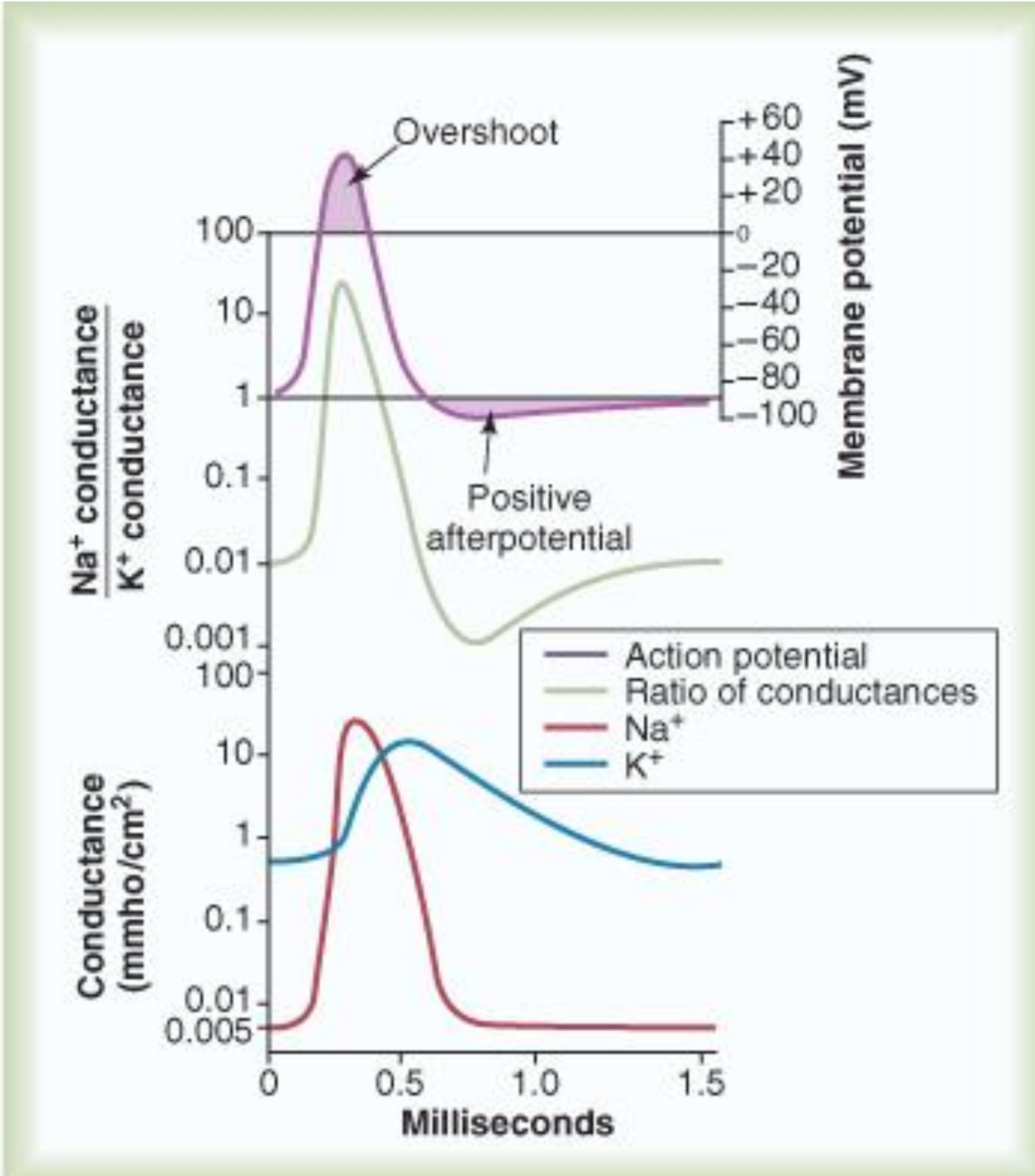
STAGES OF ACTION POTENTIAL

- Resting stage (RMP) is -90 mV
- Depolarization is change of RMP from -90 mV to 0 and then over shoot to +35 mV is called depolarization. Due to Na+ influx through voltage-gated Na+ channels.
- Repolarization is change of membrane potential from +35 to again -90 mV (RMP) is called repolarization. Due to K+ out flux through voltage-gated K+ channels.


A
B
C
D

ACTION POTENTIAL (CONTINUED)

- **Spike Potential:** Initial very large change in membrane potential is called spike potential. Also called nerve impulse.
- **Negative after potential**: At termination of spike potential membrane. Potential returns slowly to its resting level this is called negative after potential. Occurs after a series of repeated action potential.
- **Positive after potential(Hyperpolarization**):After action potential is over, membrane potential become more negative, this is called or hyperpolarization.



Overshoot
Positive afterpotential
Na⁺ conductance / K⁺ conductance
Membrane potential (mV)
+60
+40
+20
0
−20
−40
−60
−80
−100
100
10
1
0.1
0.01
0.001
Action potential
Ratio of conductances
Na⁺
K⁺
Conductance (mmho/cm²)
0.005
0
0.5
1.0
1.5
Milliseconds

THRESHOLD FOR INITIATION OF ACTION POTENTIAL

- Minimal rise in RMP that can initiate action potential is called threshold for initiation of action potential.
- Value: When membrane potential becomes -65mV(Between -70 and -50mV)due to any stimulus, it opens voltage gated Na+ channels, thereby initiating actionpotential.So,threshold is -65mV.

STIMULI FOR INITIATION OF ACTION POTENTIAL

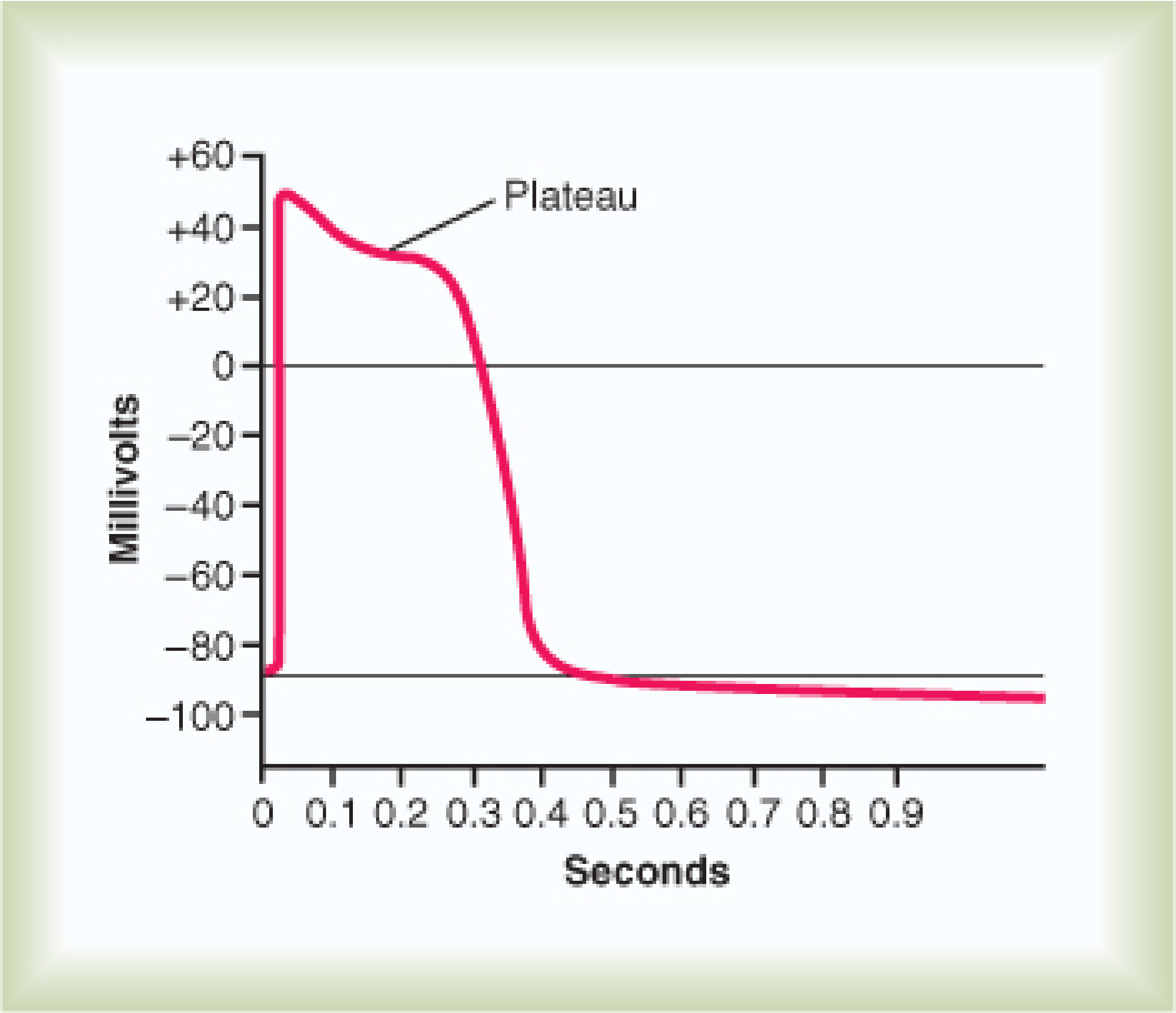
- Any factor that causes Na+ influx
- **Chemical stimuli** are acetylcholine,norepinephrine and epinephrine for example(adrenaline and nor adrenaline) and the rest of the neurotransmitters.
- **Mechanical stimuli** are crushing, pinching and pricking.

SUB THRESHOLD POTENTIAL

- Potential below threshold level that cannot initiate action potential is called sub threshold potential.
- ALL OR NOTHING PRINCIPAL(All or none law):Action potential fails to occur if stimuli is **sub threshold** and it occurs with a constant amplitude and form if stimulus is at or **above threshold in intensity**; this is called all or nothing principal or all or none law.

PLATEAU IN SOME ACTION POTENTIALS

- Causes are voltage gated slow Ca+ Na+ channels
- Plateau in action potential prolongs duration of action potential and muscle contraction, mainly present in cardiac and smooth muscle
- **IMPULSE** is the transmission or propagation of depolarization wave along a nerve or muscle fiber.

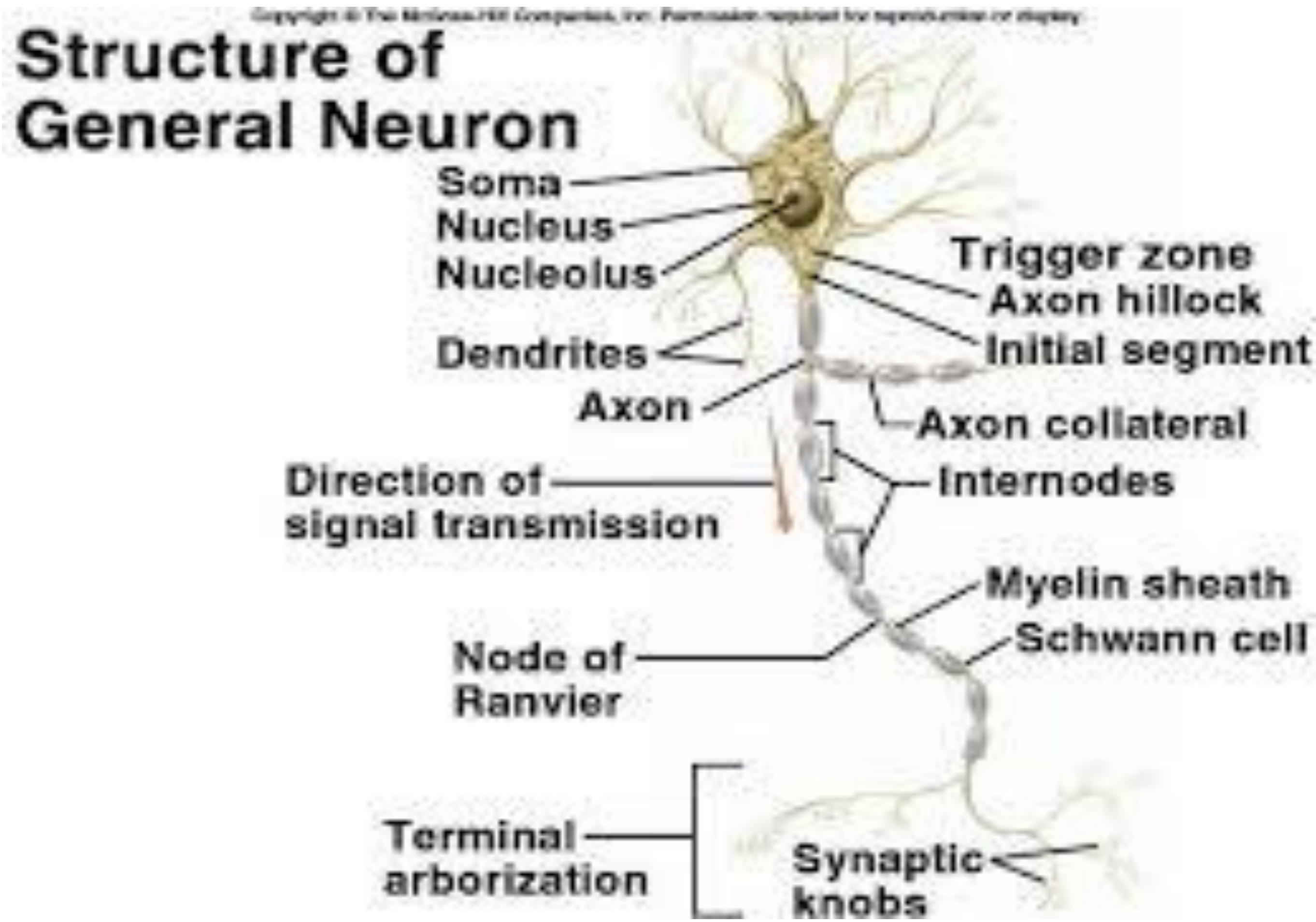

+60
+40
+20
0
−20
−40
−60
−80
−100
Millivolts
Plateau
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9
Seconds

REFRACTORY PERIOD

- Period during which a second action potential cannot occur in presence of first action potential, is called refractory period.
- Absolute refractory period is the period during which a second action potential cannot be elicited even with a very strong stimulus. Example is stimulus during depolarization.
- **Relative refractory period** is the period during which stronger then normal stimuli can cause a second action potential. Example is stimulus given during repolarization.

NERVE FIBER

- **Nerve Fiber**: Axon of neuron is called nerve fiber.
- **Unmyelinated nerve fiber**: axon or nerve fiber is not covered by myelin sheath
- **Myelinated nerve fiber**: Axon or nerve fiber is covered by myelin sheath.


Structure of
General Neuron
Soma
Nucleus
Nucleolus
Trigger zone
Axon hillock
Initial segment
Dendrites
Axon
Axon collateral
Direction of
signal transmission
Internodes
Myelin sheath
Schwann cell
Node of
Ranvier
Terminal
arborization
Synaptic
knobs

MYELINATED FIBER

- The central core of the fiber is axon.
- The axon is filled in its center with axoplasm,which is a viscid intracellular fluid.
- Surrounding the axon is myelin sheath that is often much thicker then the axon itself.

MYELINATED FIBER

- Myelinated fibers,as the name implies,are covered with myelin at regular, intervals along the length of the axon.
- Myelin is composed primarily of lipids.
- Myelin coating act as an insulator.
- Myelin is not actually a part of the nerve cells but consists of separate myelin forming cells,the myelin forming cells are oligodendrocytes in the central nervous system(the brain and spinal cord)and Schwann cells in the peripheral nervous system.
- The lipid composition of myelin is due to the presence of layer on layer of the lipid bilayer that composes the plasma membrane of these myelin forming.

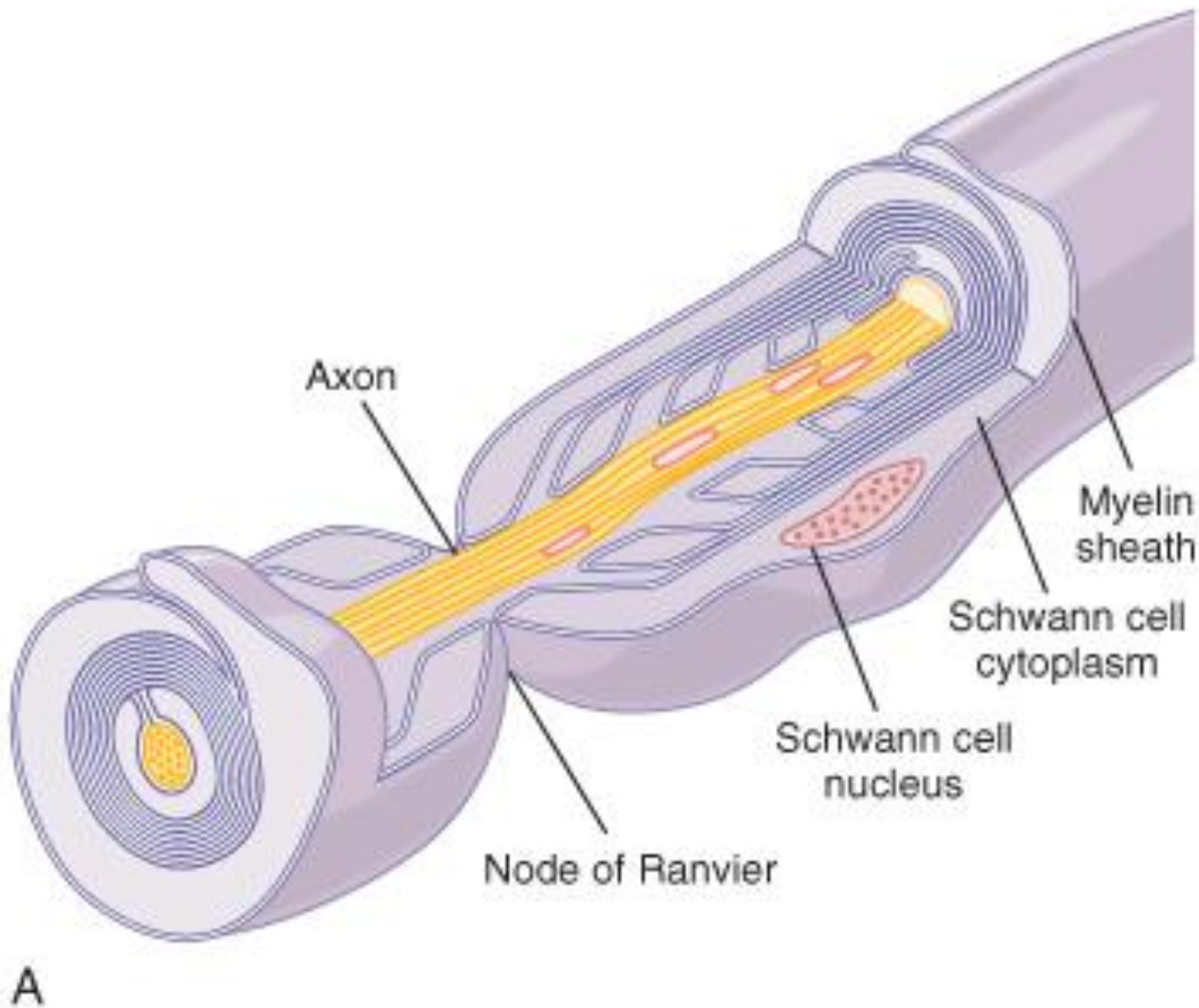
MYELINATED FIBER

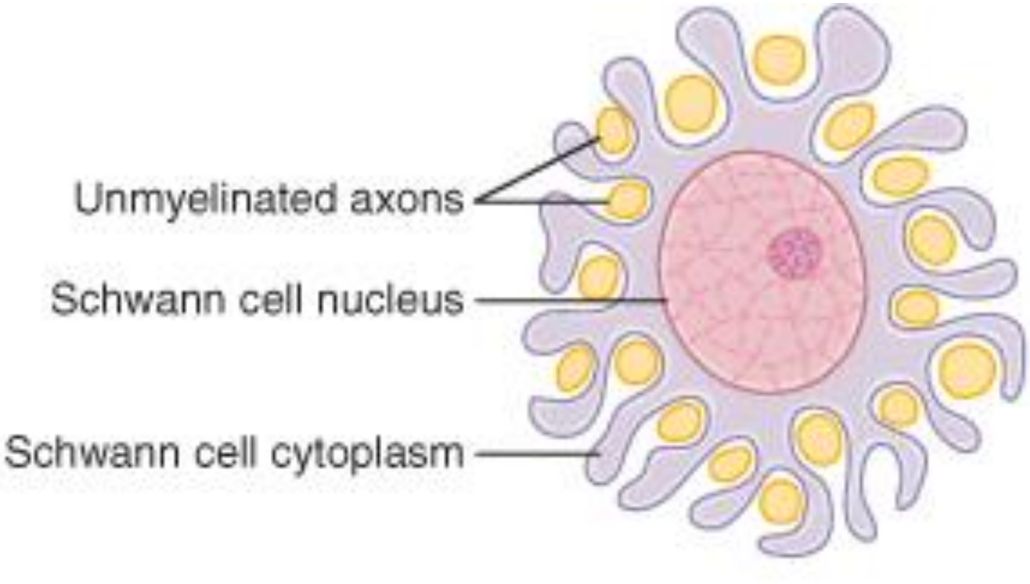
- The membrane of a Schwann cell first envelops the axon. The Schwann cell rotates around the axon many times laying down multiple layers of Schwann cell membrane containing the lipid substance Sphingomyelin(an excellent electrical insulator) that decreases ion flow through the membrane about 5000 fold.

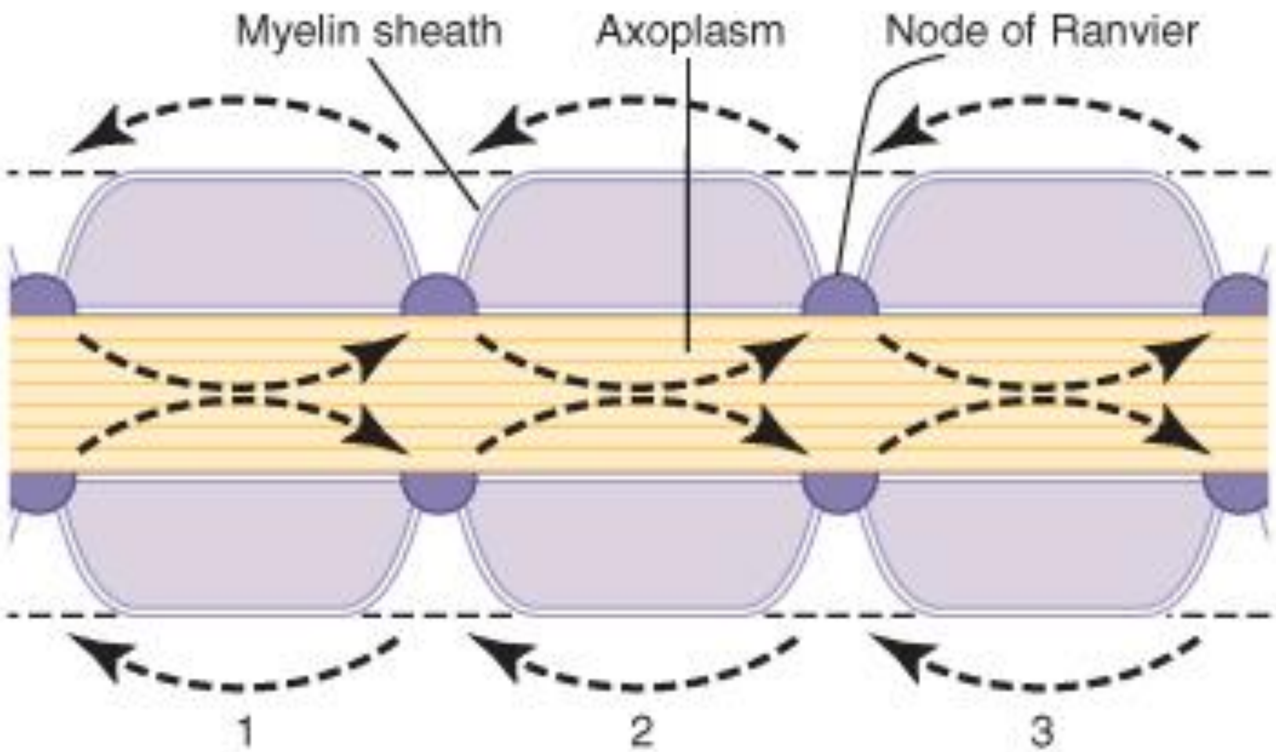
NODE OF RANVIER

- At the junction between each two successive schawann cells along the axon, an uninsulated area only 2 to 3 micrometers in length remains where ions still can flow easily through the axon membrane between the extracellular and intracellular fluid inside the axon. This area is called Node of Ranvier.
- At the node of ranvier the axonal membrane is bare and exposed to the ECF.
- It is only at these bare spaces that current can flow across the membrane to produce action potential as the voltage gated Na channels are concentrated at the nodes.
- The nodes are usually 1mm apart.

- When an action potential occurs at one node opposite charges attract from the adjacent inactive node,reducing its potential to threshold so that it undergoes an action potential and so on.
- When fiber diameter increases the resistance to local current decreases.Thus the larger the diameter of the nerve fiber, the faster it can propagate action potential.
- “SALTATORY CONDUCTION” in myelinated


Axon
Myelin sheath
Schwann cell cytoplasm
Schwann cell nucleus
Node of Ranvier
A


Unmyelinated axons
Schwann cell nucleus
Schwann cell cytoplasm
B



Myelin sheath
Axoplasm
Node of Ranvier
1
2
3

- Large myelinated fibers such as those supplying skeletal muscles can conduct action potential at a speed of upto 120meters/sec or 360miles/hr,compared with a conduction velocity of 0.7meters/sec(2 miles/hr) in unmyelinated fibers such as those supplying the digestive tract.

VALUE OF SALTATORY CONDUCTION

- Causing the depolarization process to **jump long** intervals along the axis of the nerve fibre.
- **Increases the velocity of nerve transmission** in myelinated fibres as much as 5 to 50 fold.
- **Conserves energy for the axon** because only the nodes depolarize .
- Causes, **less loss of ions 100 times** then other wise necessary.

MULTIPLE SCLEROSIS

- Multiple sclerosis (MS) affects women more than men. The disorder is most commonly diagnosed between ages 20 and 40, but can be seen at any age.
- MS is caused by damage to the myelin sheath, the protective covering that surrounds nerve cells. When this nerve covering is damaged, nerve signals slow down or stop.
- The nerve damage is caused by inflammation. Inflammation occurs when the body's own immune cells attack the nervous system. This can occur along any area of the brain, optic nerve, and spinal cord. Muscle symptoms: Loss of balance, muscle spasms, Numbness
- Problems with coordination and making small movements
- Tremor in one or more arms or legs
- Weakness in one or more arms or legs