MEMBRANE POTENTIAL(MP)

Assis.Prof.Dr.Azza Sajid

Physiology -2nd stage

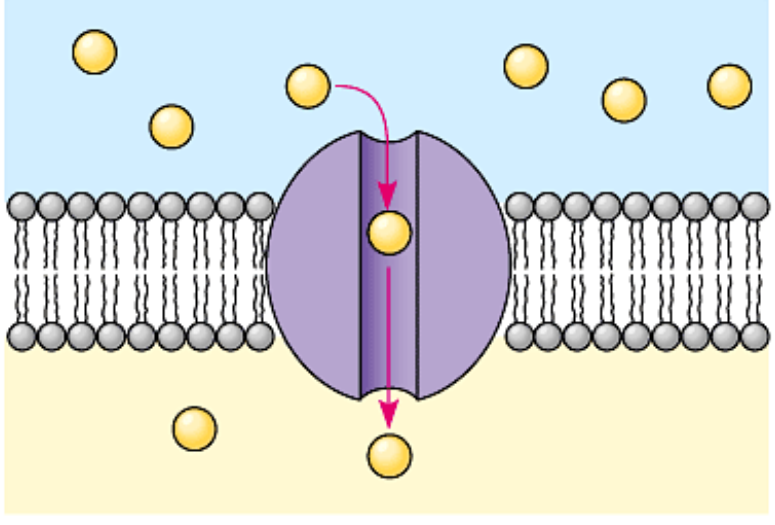
2018-2019

Membrane ions channels

Membrane proteins of plasma membrane act as ion channels which are selective to the type of ions .

Ex:K+channels allow only K+ to pass .

Membrane channels are large proteins with several subunits of a.a chains across the membrane.



(a)

Types of ions channels

1-Leakage (non-gated channels):

Are always open ,have no gates .

2-Gated channels :with gates

a-chemically gated or ligand gated channels:

open when approperiate chemicals bind (neurotransmitters).

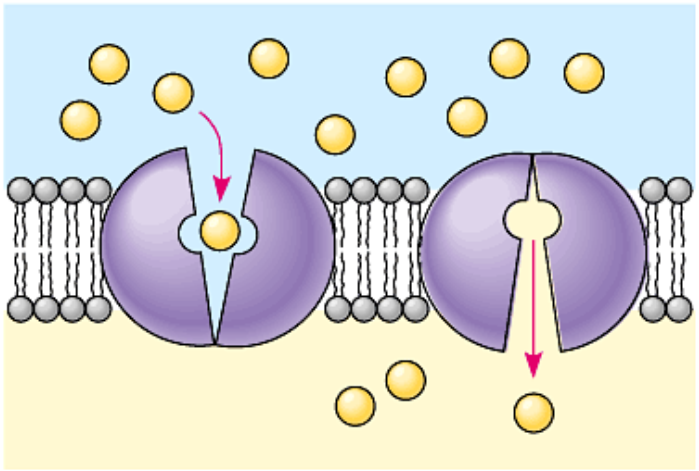
b-voltage gated channels (electrical):

Open &close in response to change in membrane potential.

c-mechanically gated channels :

Open in response to physical deformation of the receptors,(sensory receptors for touch &pressure)

These shape changes could be triggered by the binding and release of the transported molecule.



(b)

- When gated ions channels are open ,ions diffuse across the plasma membrane following their electrochemical gradients creating electrical current &voltage changes across the plasma membrane, according to Ohm's lawequation:

$$V = I * R$$

V=voltage

I=current

R=resistance

Electrochemical gradients :referrers to both electrical &chemical concentration gradients .

It is ions flow along electrochemical gradients.

Membrane potential &
resting membrane potential

Potential differences across the plasma membrane is known as: membrane potential or

Voltage .

In the resting state ,all body cells exhibit a resting membrane potential.

That range from -50 –(-100) Mv depending on cell type.

The minus sign indicates that the inside the cell is negative compared to its outside .

This voltage exists only at the membrane .

The cell interior (cytoplasm) is electrically neutral

The extracellular fluid is electrically neutral .

But :the membrane shows membrane potential ,this is because ;

1-DIFFUSION : causes ionic imbalance that polarize the membrane .

2-ACTIVE TRANSPORT: maintain the membrane potential .

How diffusion polarize the membrane?

- The RMP is generated by the differences in the ionic makeup of intercellular & extracellular fluid & by differential permeability of the membrane to these ions .
- The cell cytosol contains a lower conc. of Na^+
- And higher conc. of K^+ than extracellular fluid .
- RMP is determined mainly by :***conc.gradient of***
- ***K^+*** and by the ***differential permeability of membrane to K^+***

- Intracellular fluid ⟶ K+ and protein anion A-
- Extracellular fluid ⟶ Na+ balanced by Cl-
- ***1-The role of K+ in the generation of RMP:***
- Plasma membrane is permeable to K+(presence of leakage channels) and impermeable to A- ,so K+ diffuse out of the cell along its conc. gradients making membrane interior more negative .

- The negativity of the inner membrane face becomes great enough to attract K+ into the cell again .

- A negative MP (-90 mV)is established when the movement of K+ out of the cell equals its movement into the cell .At this point K+ conc. gradient is balanced by electrical gradient .
-

2-Na+ contribution to RMP

- Na+ is attracted to the cell interior by the conc.gradients(diffusion),bringing the RMP to(-70 mV).
- K+ is more determiner to cell mp because the membrane contains leakage channels to K+ &even though the membrane is permeable to Cl- in most cells,Cl- does not contribute to the RMP because :
- ***Cl- entry is resisted by negative charge of interior face .***

No. of ions producing mp is so small that it does not change ion conc. in any significant way.

3-Role of active transport in maintenance of membrane potential :

- Active transport process maintain mp that diffusion has established ,so the cell exhibits(a steady state).
- The rate of active transport is equal &depend on Na+ diffusion into the cell :
- If ↑ Na+ diffuse into the cell ⟹ ↑Na+ pump out.

- The **sodium-potassium pump** actively maintains the gradient of sodium (Na^+) and potassium ions (K^+) across the membrane.
  - Typically, the cell has higher concentrations of K^+ and lower concentrations of Na^+ inside the cell.
  - The sodium-potassium pump uses the energy of one ATP to pump **three Na^+** ions out and **two K^+** ions in.
  - Because the membrane is 50 -100 time more permeable to K+,ATP dependent Na+-K+ maintain both mp &osmotic pressure :if Na+ was not continuously removed ⟶ so much accumulated intercellularly ⟶ osmotic p
  - Would draw water into the cell ⟶ burst of cell.

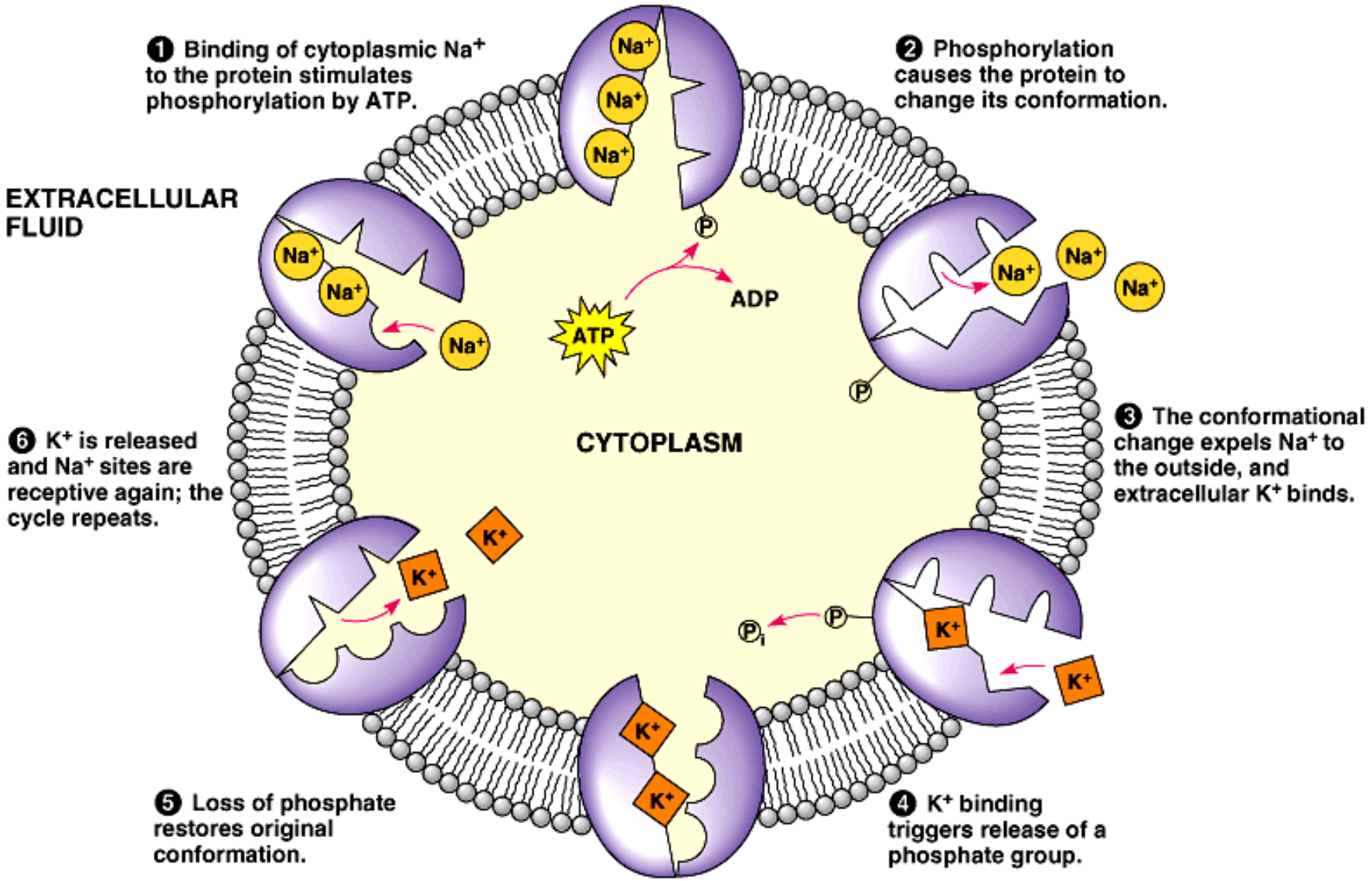
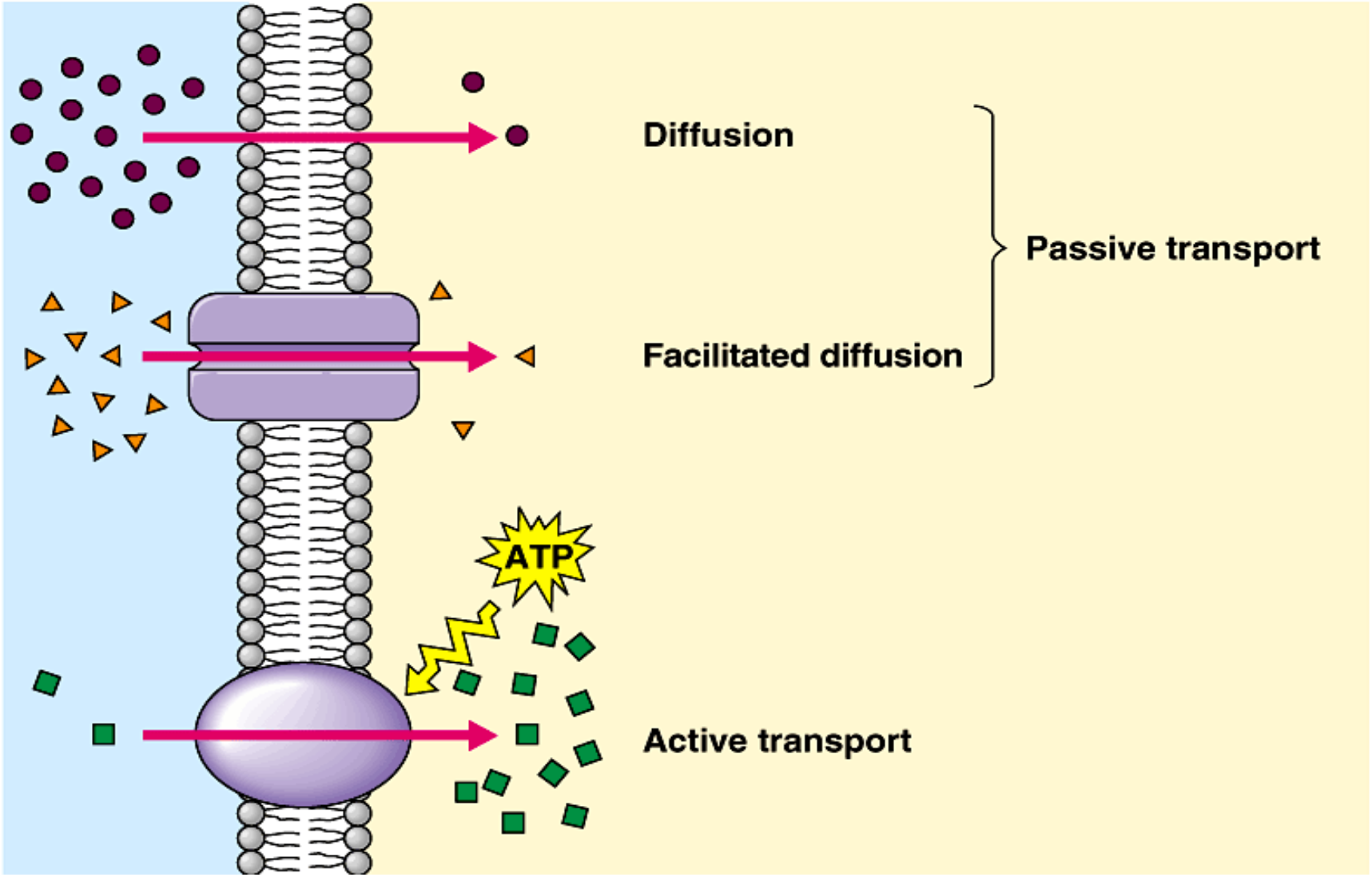


Fig. 8.15

- So it is more correct to say that ions diffusion occurs according electrochemical gradients: recognizing the effect of both electrical charge &conc.(chemical) of ions.



Both diffusion and facilitated diffusion are forms of passive transport of molecules down their concentration gradient, while active transport requires an investment of energy to move molecules against their concentration gradient.

9. Exocytosis and endocytosis transport large molecules

- Small molecules and water enter or leave the cell through the lipid bilayer or by transport proteins.
- Large molecules, such as polysaccharides and proteins, cross the membrane via vesicles.
- During **exocytosis**, a transport vesicle budded from the Golgi apparatus is moved by the cytoskeleton to the plasma membrane.
- When the two membranes come in contact, the bilayers fuse and spill the contents to the outside.

- During **endocytosis**, a cell brings in macromolecules and particulate matter by forming new vesicles from the plasma membrane.
- Endocytosis is a reversal of exocytosis.
  - A small area of the palsma membrane sinks inward to form a pocket
  - As the pocket into the plasma membrane deepens, it pinches in, forming a vesicle containing the material that had been outside the cell

- One type of endocytosis is **phagocytosis**, "cellular eating".
- In phagocytosis, the cell engulfs a particle by extending pseudopodia around it and packaging it in a large vacuole.
- The contents of the vacuole are digested when the vacuole fuses with a lysosome.

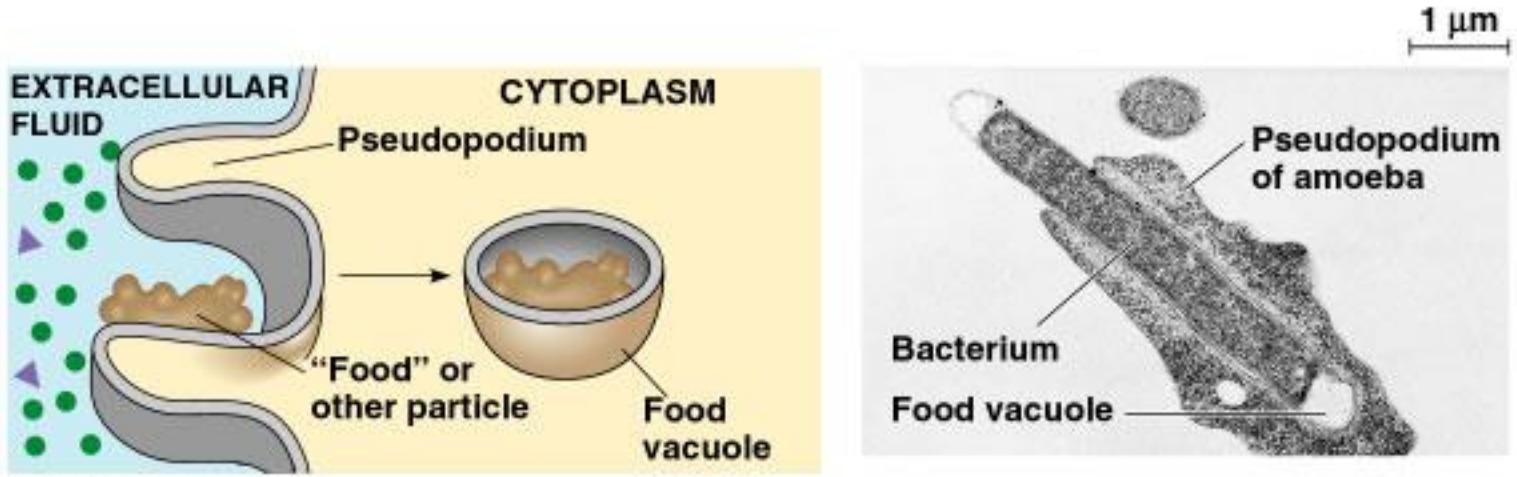


Fig. 8.19a (a) Phagocytosis

- In **pinocytosis**, "cellular drinking", a cell creates a vesicle around a droplet of extracellular fluid.
  - This is a non-specific process.

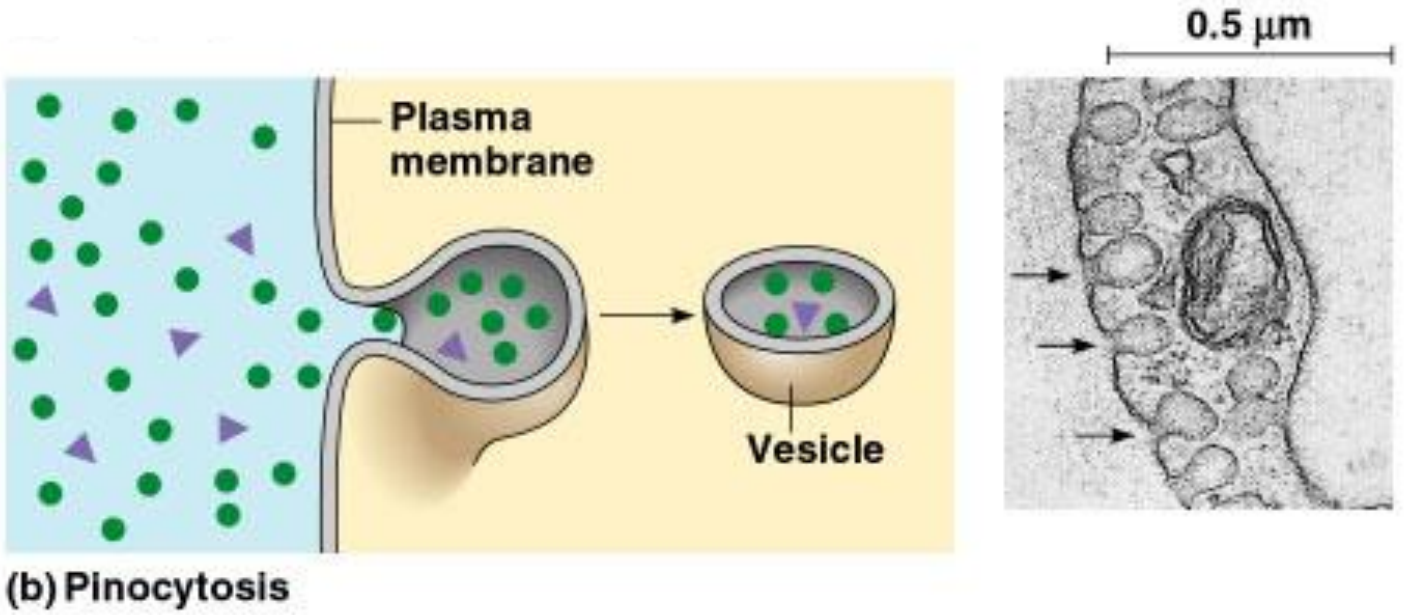


Fig. 8.19b (b) Pinocytosis

- **Receptor-mediated endocytosis** is very specific in what substances are being transported.
- This process is triggered when extracellular substances bind to special receptors, **ligands**, on the membrane surface, especially near coated pits.
- This triggers the formation of a vesicle

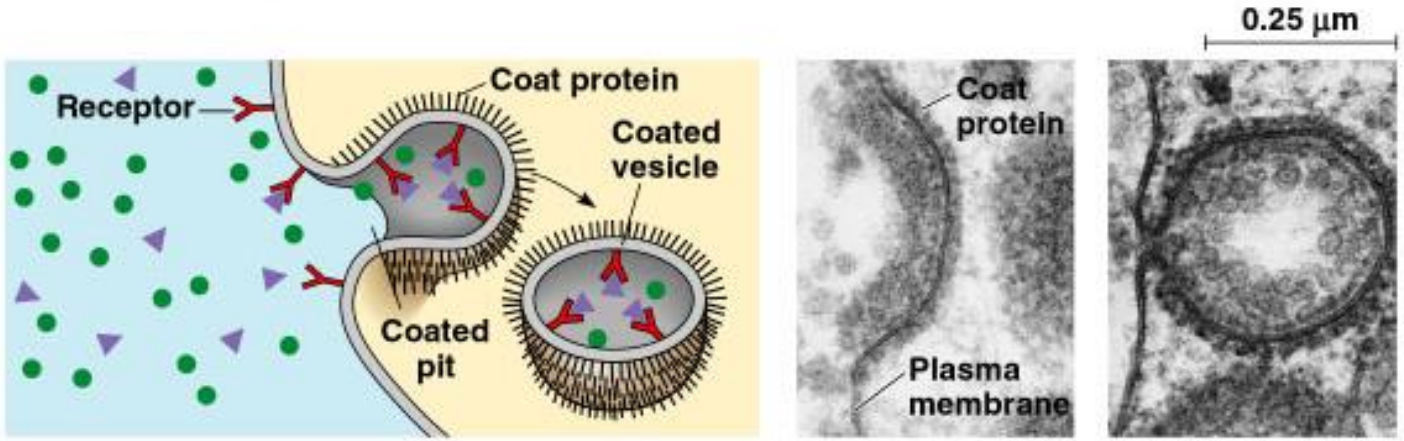


Fig. 8.19c (c) Receptor-mediated endocytosis

- Receptor-mediated endocytosis enables a cell to acquire bulk quantities of specific materials that may be in low concentrations in the environment.
  - Human cells use this process to absorb cholesterol.
  - Cholesterol travels in the blood in low-density lipoproteins (LDL), complexes of protein and lipid.
  - These lipoproteins bind to LDL receptors and enter the cell by endocytosis.
  - In familial hypercholesterolemia, an inherited disease, the LDL receptors are defective, leading to an accumulation of LDL and cholesterol in the blood.
  - This contributes to early atherosclerosis.

NERVOUS SYSTEMS

The Nature Of Nerve Signals

1. Every cell has a voltage, or membrane potential, across its plasma membrane
2. Changes in the membrane potential of a neuron give rise to nerve impulses
3. Nerve impulses propagate themselves along an axon

1. Every cell has a voltage, or membrane potential, across its plasma membrane

- A **membrane potential** is a localized electrical gradient across membrane.
  - Anions are more concentrated within a cell.
  - Cations are more concentrated in the extracellular fluid.

- Measuring Membrane Potentials.

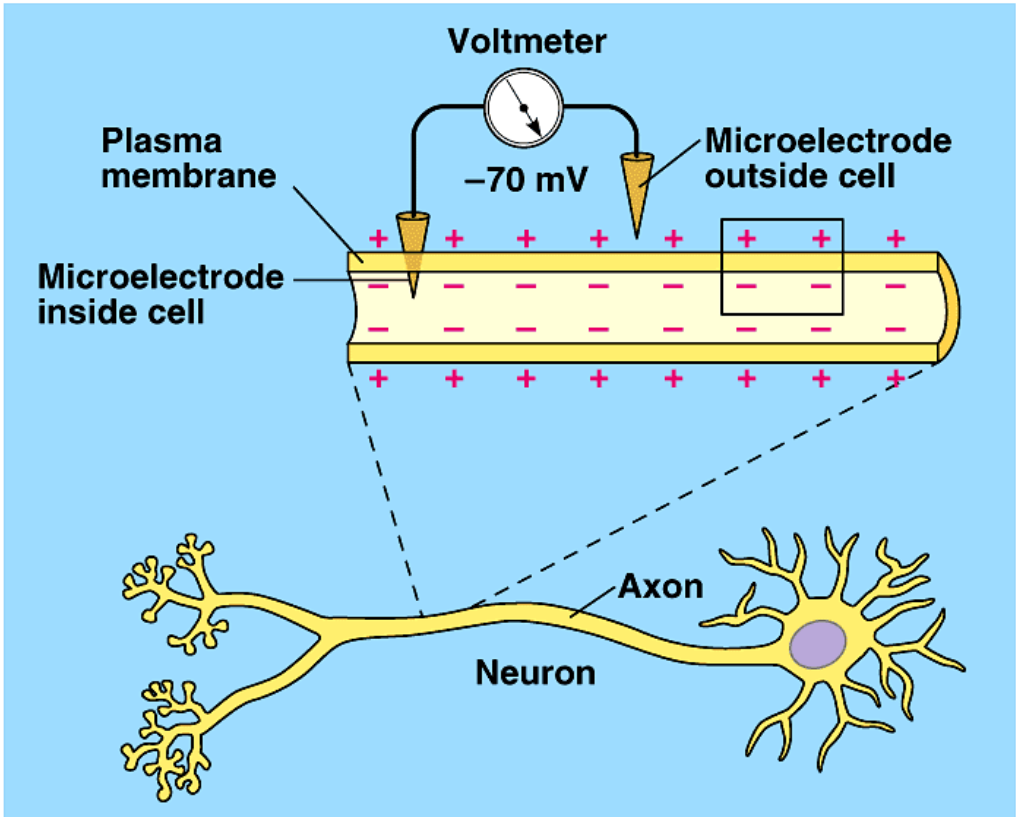


Fig. 48.6a

- An unstimulated cell usually have a **resting potential** of -70mV.

- How a Cell Maintains a Membrane Potential.
  - Cations.
    - K^+ the principal intracellular cation.
    - Na^+ is the principal extracellular cation.
  - Anions.
    - Proteins, amino acids, sulfate, and phosphate are the principal intracellular anions.
    - Cl^- is principal extracellular anion.

- **Ungated ion channels** allow ions to diffuse across the plasma membrane.
  - These channels are always open.
- This diffusion does not achieve an equilibrium since sodium-potassium pump transports these ions against their concentration gradients.

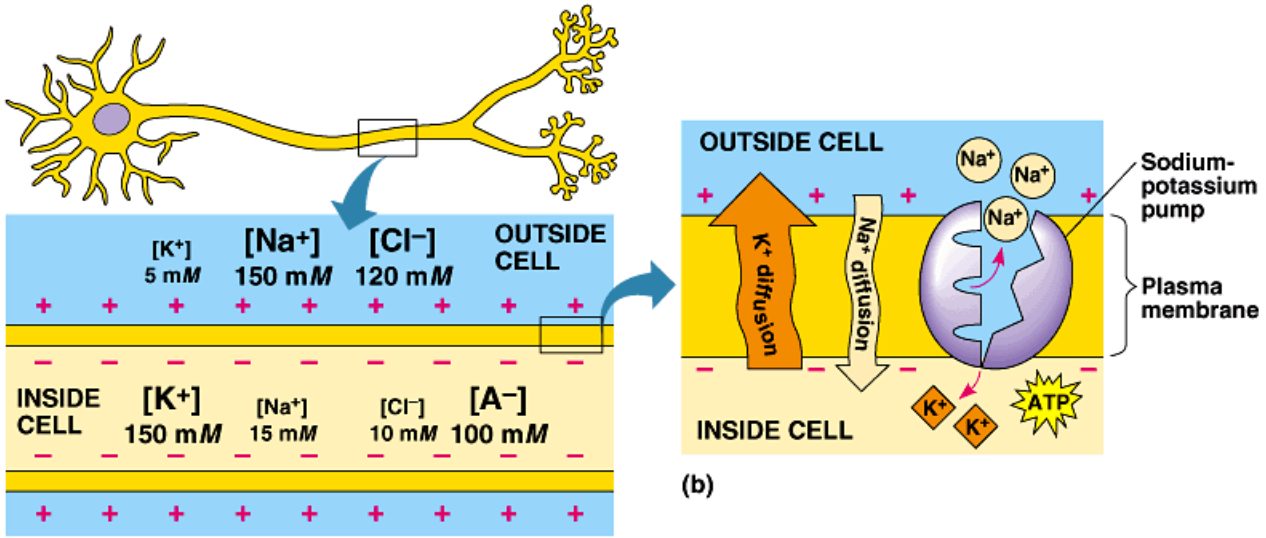


Fig. 48.7

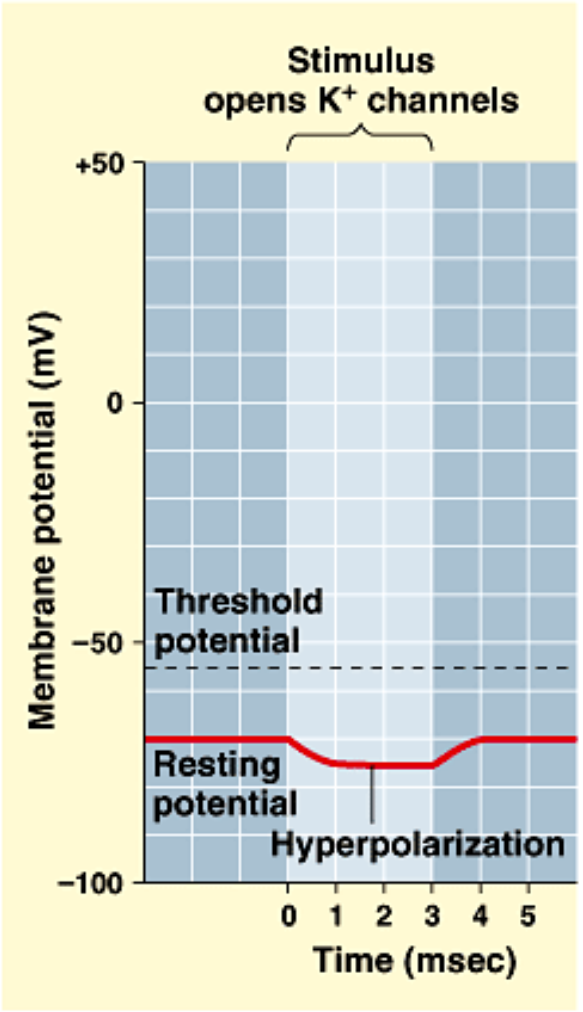
2. Changes in the membrane potential of a neuron give rise to nerve impulses

- **Excitable cells** have the ability to generate large changes in their membrane potentials.
  - **Gated ion channels** open or close in response to stimuli.
    - The subsequent diffusion of ions leads to a change in the membrane potential.

- Types of gated ions.
  - **Chemically-gated ion channels** open or close in response to a chemical stimulus.
  - **Voltage-gated ion channels** open or close in response to a change in membrane potential.

- Graded Potentials: Hyperpolarization and Depolarization
  - **Graded potentials** are changes in membrane potential

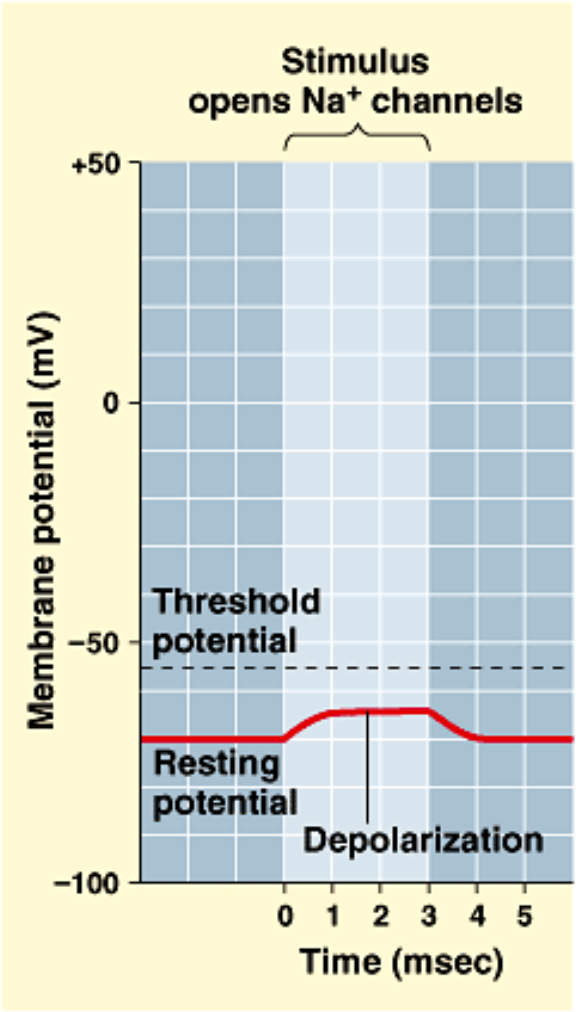
- **Hyperpolarization.**
  - Gated K^+ channels open $\rightarrow$ K^+ diffuses out of the cell $\rightarrow$ the membrane potential becomes more negative.



(a) Graded potential: hyperpolarization

Fig. 48.8a

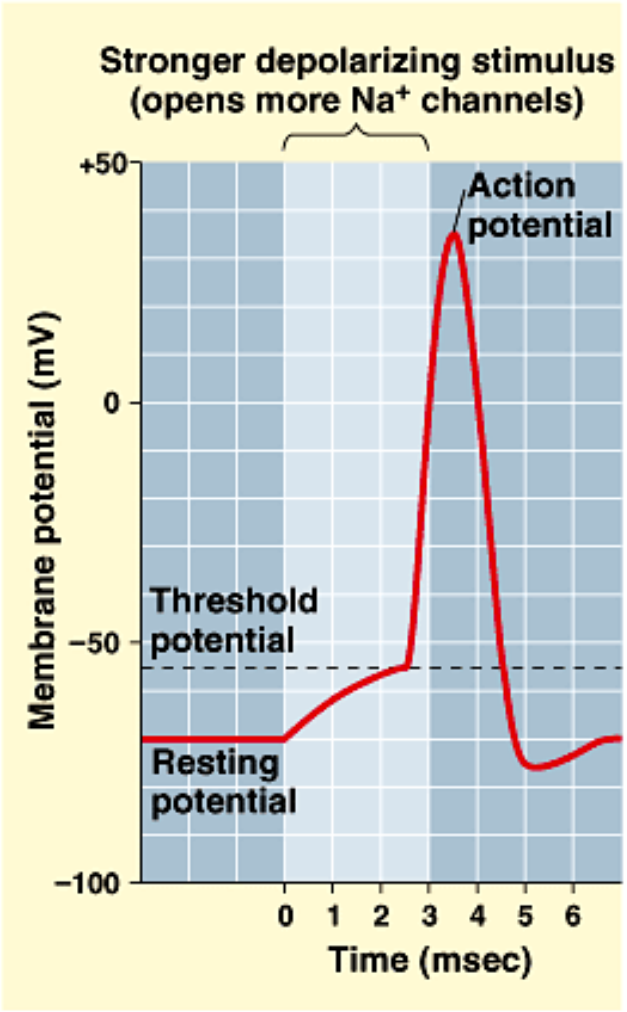
- **Depolarization.**
  - Gated Na^+ channels open $\rightarrow$ Na^+ diffuses into the cell $\rightarrow$ the membrane potential becomes less negative.



(b) Graded potential: depolarization

Fig. 48.8b

- The Action Potential: All or Nothing Depolarization.
  - If graded potentials sum to ≈-55mV a **threshold potential** is achieved.
    - This triggers an **action potential**.
      - Axons only.



(c) Action potential

Fig. 48.8c

- In the resting state closed voltage-gated K^+ channels open slowly in response to depolarization.
- Voltage-gated Na^+ channels have two gates.
  - Closed activation gates open rapidly in response to depolarization.
  - Open inactivation gates close slowly in response to depolarization.

- Step 1: Resting State.

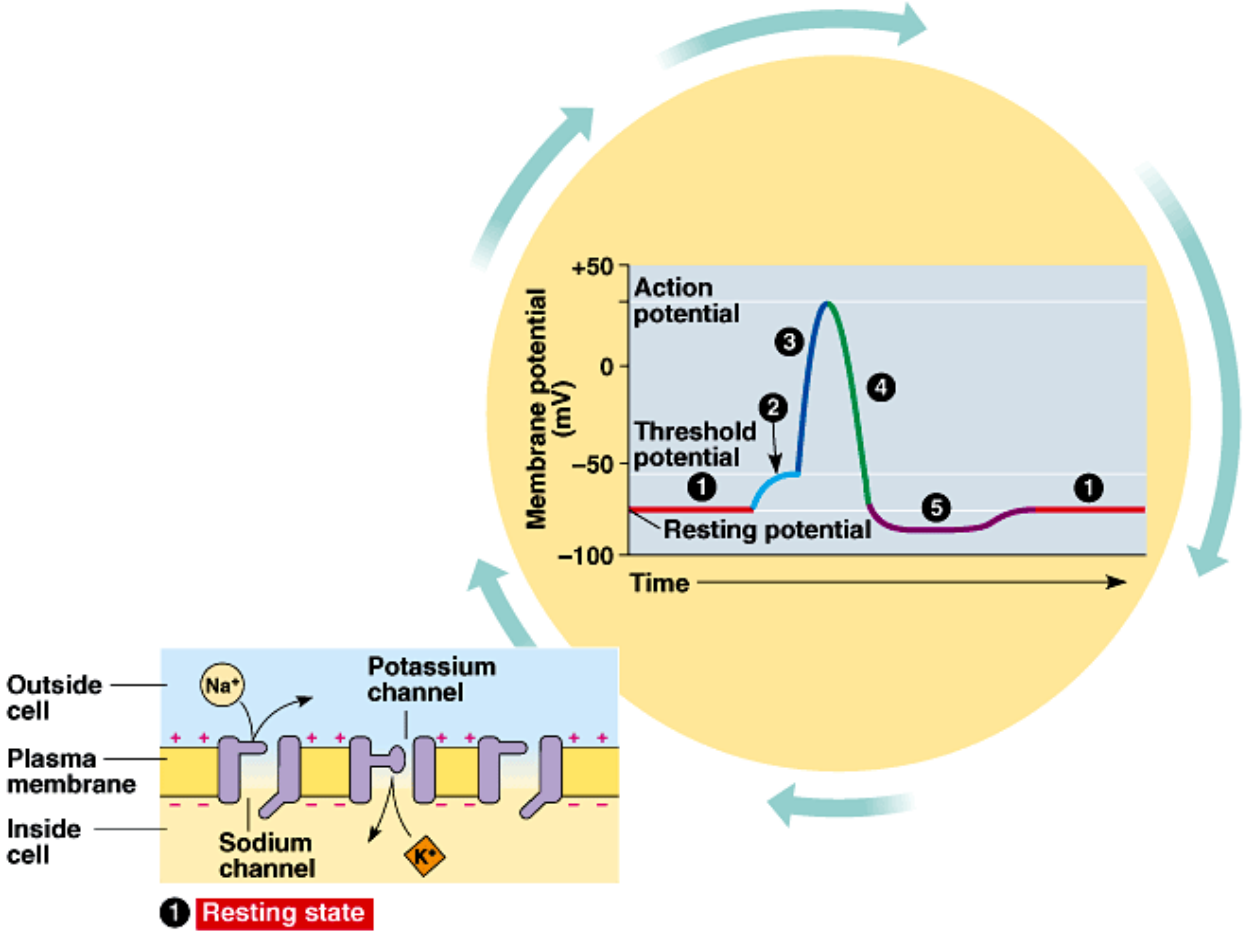


Fig. 48.9

- Step 2: Threshold.

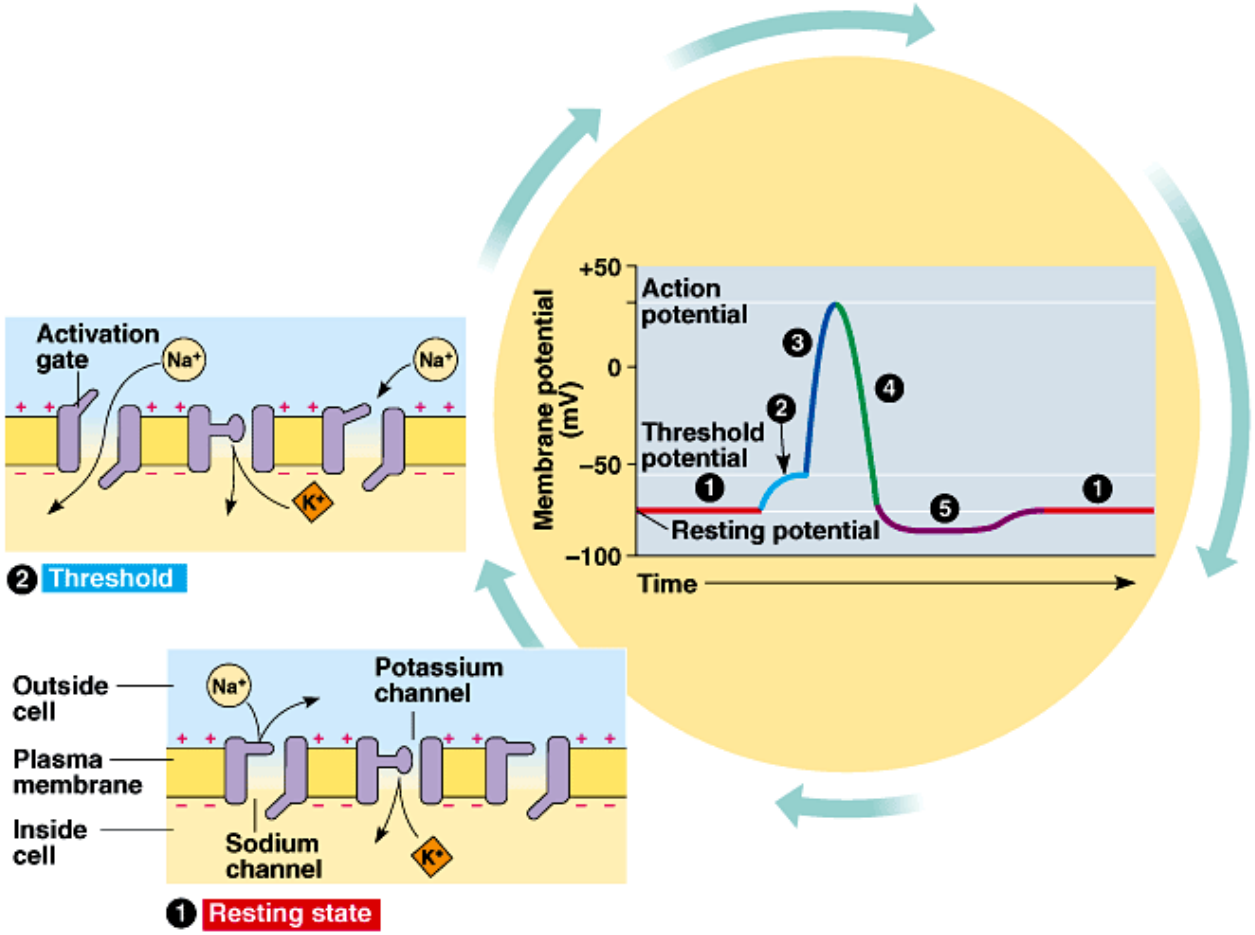


Fig. 48.9

- Step 3: **Depolarization** phase of the action potential.

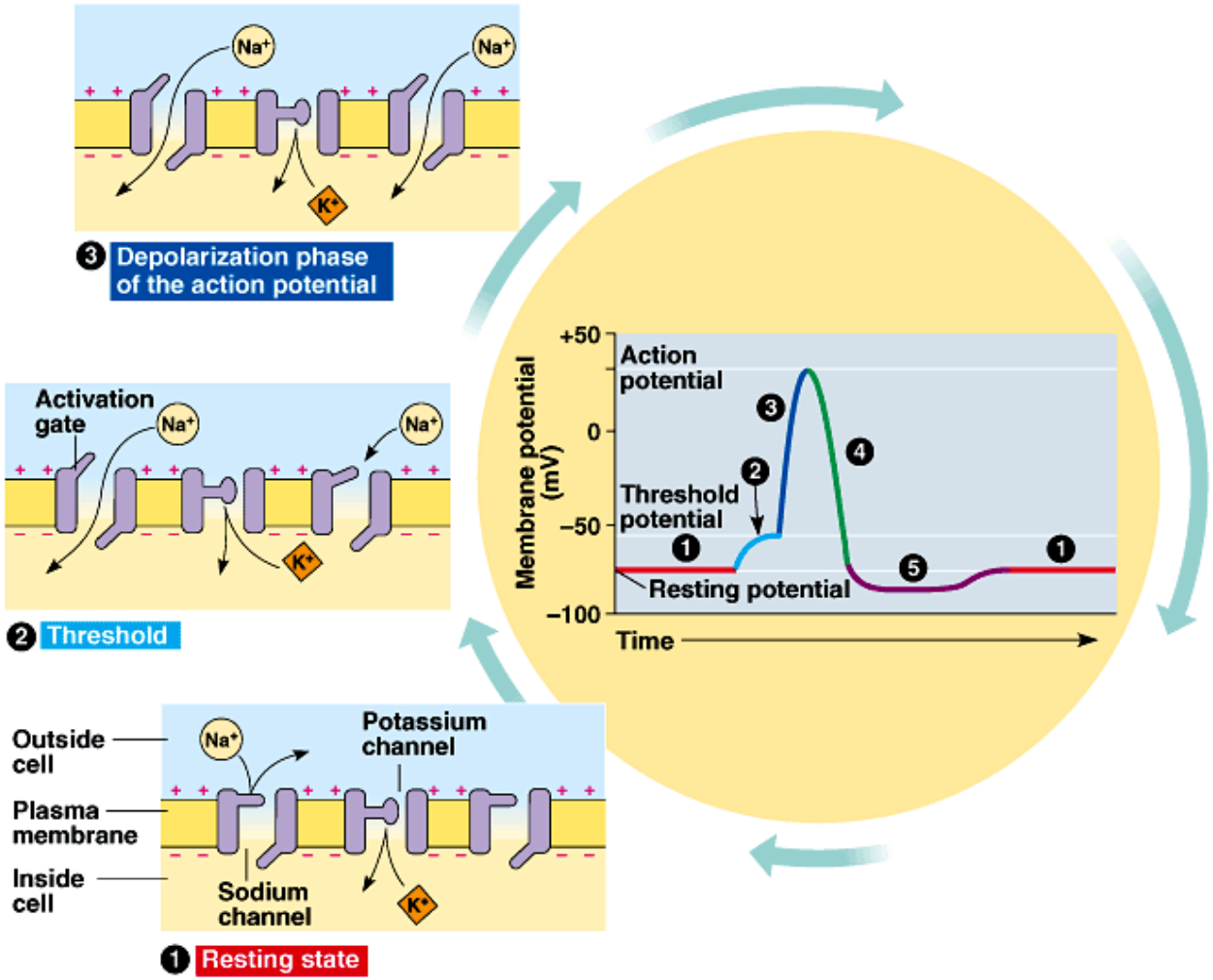


Fig. 48.9

- Step 4: Repolarizing phase of the action potential.

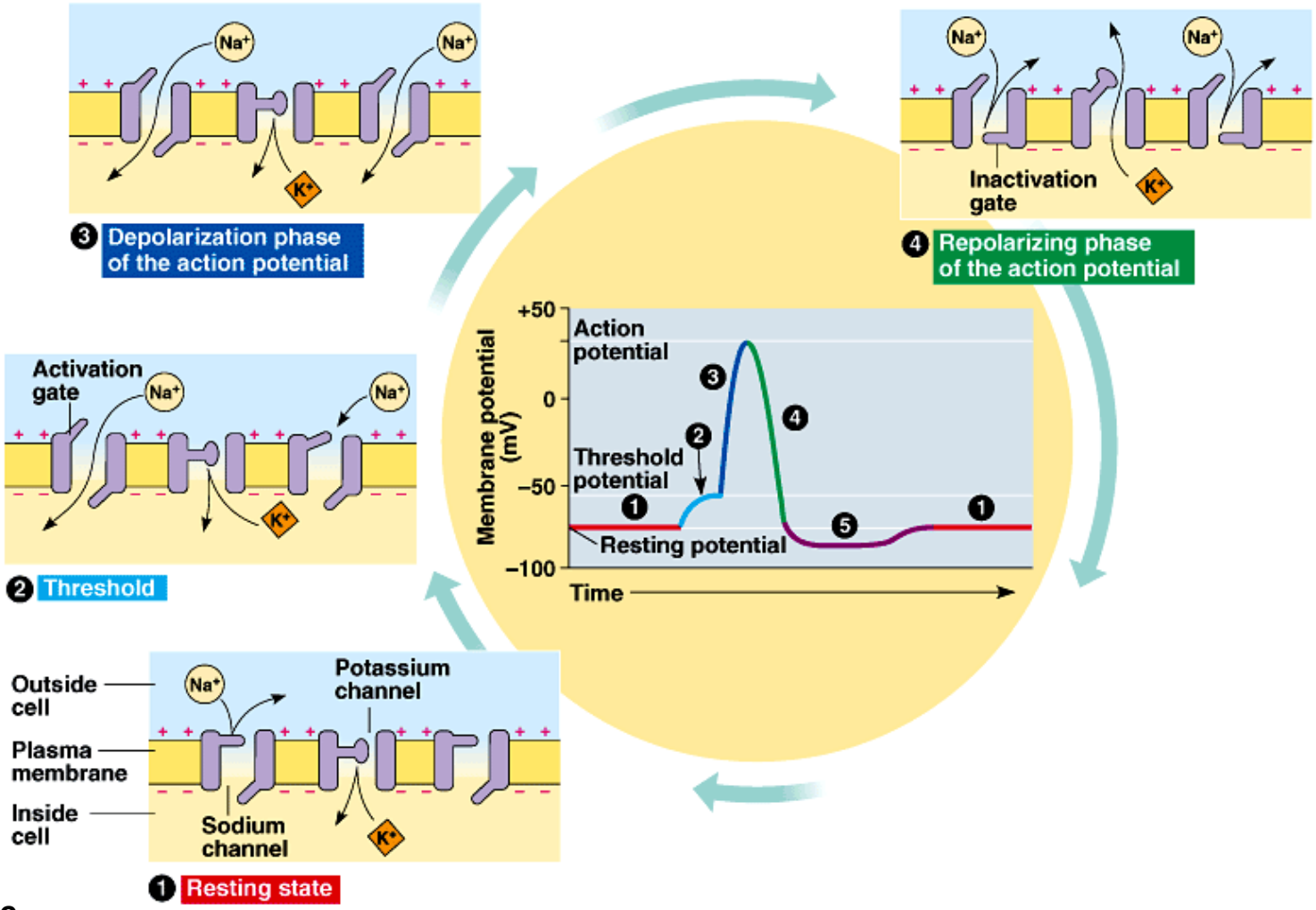


Fig. 48.9

- Step 5: Undershoot.

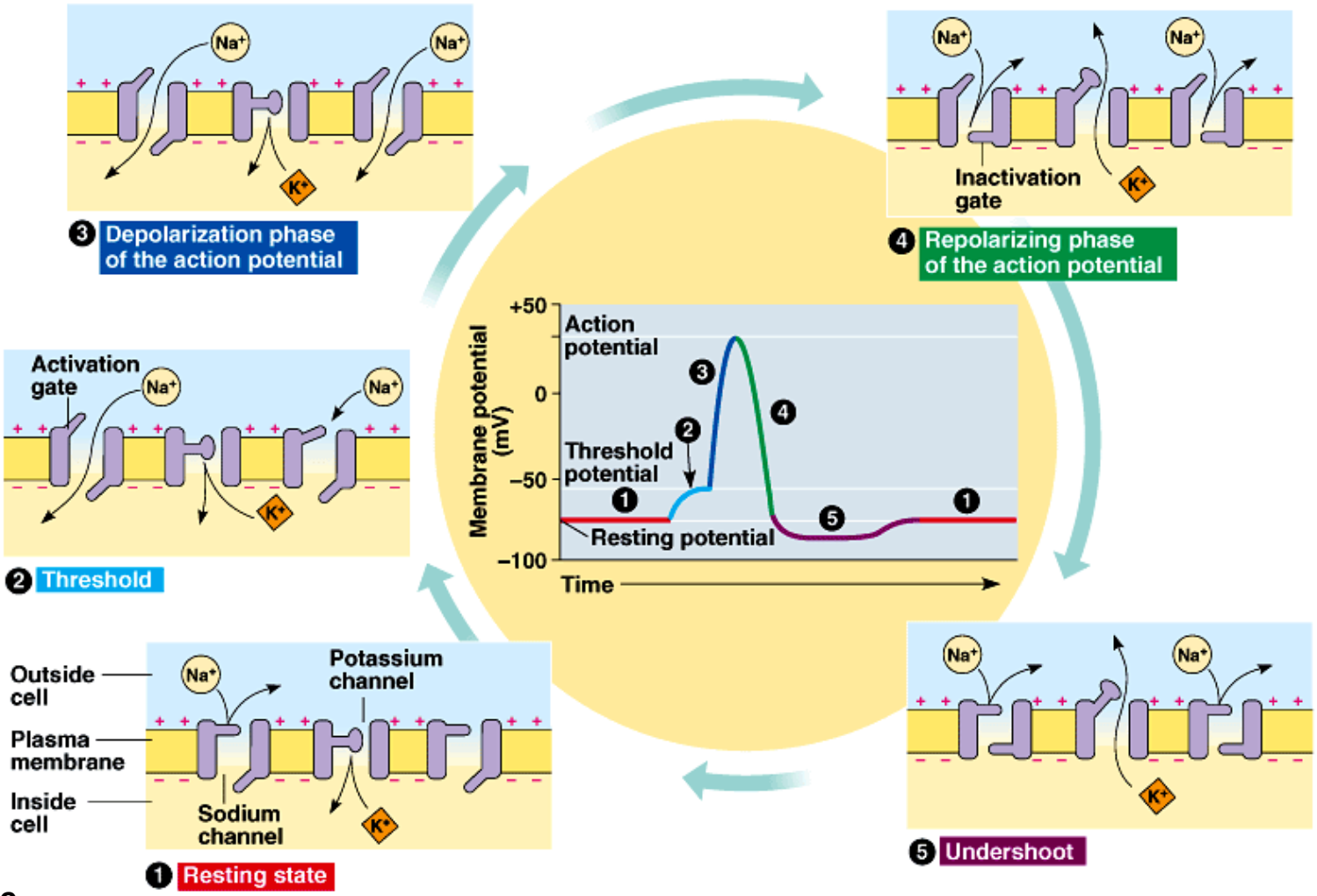


Fig. 48.9

- During the undershoot both the Na^+ channel's activation and inactivation gates are closed.
  - At this time the neuron cannot depolarize in response to another stimulus: **refractory period**.

3. Nerve impulses propagate themselves along an axon

- The action potential is repeatedly regenerated along the length of the axon.
  - An action potential achieved at one region of the membrane is sufficient to depolarize a neighboring region above threshold.
    - Thus triggering a new action potential.
    - The refractory period assures that impulse conduction is unidirectional.

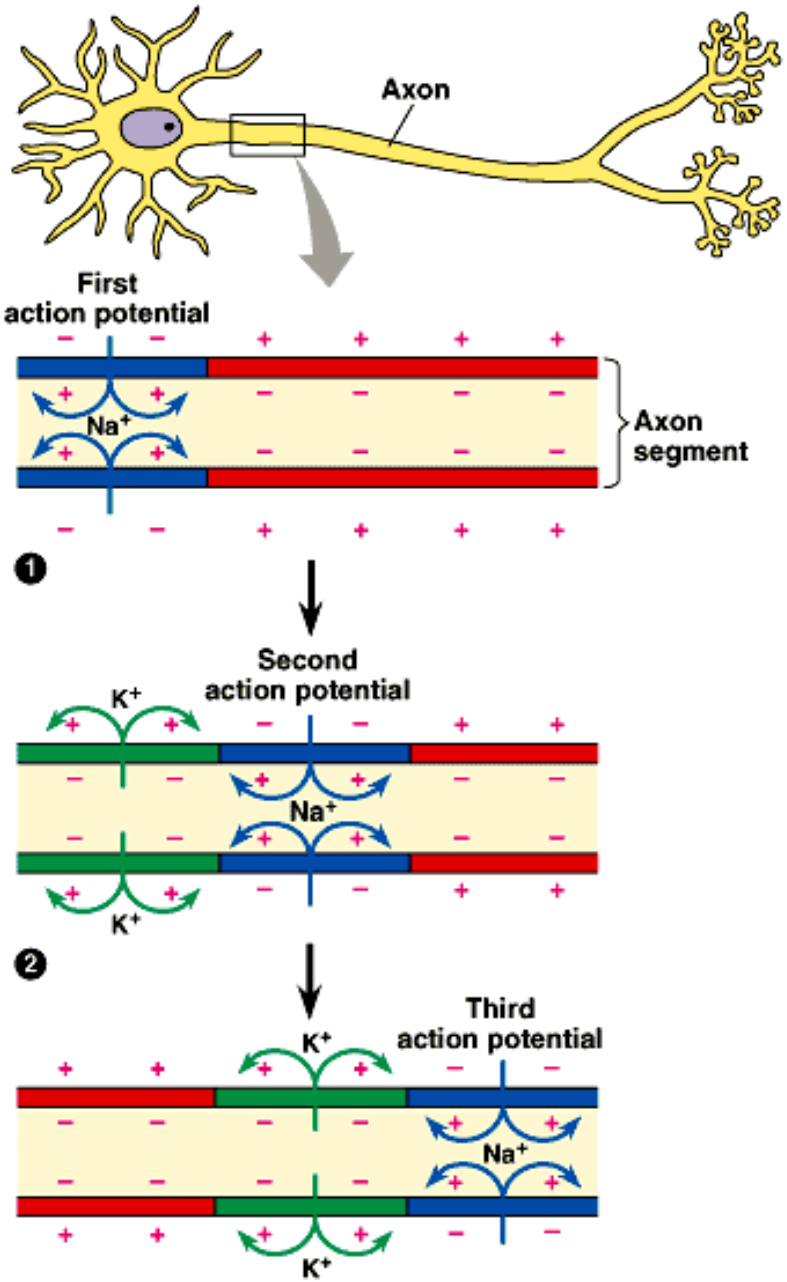


Fig. 48.10

- **Saltatory conduction.**
  - In myelinated neurons only unmyelinated regions of the axon depolarize.
    - Thus, the impulse moves faster than in unmyelinated neurons.

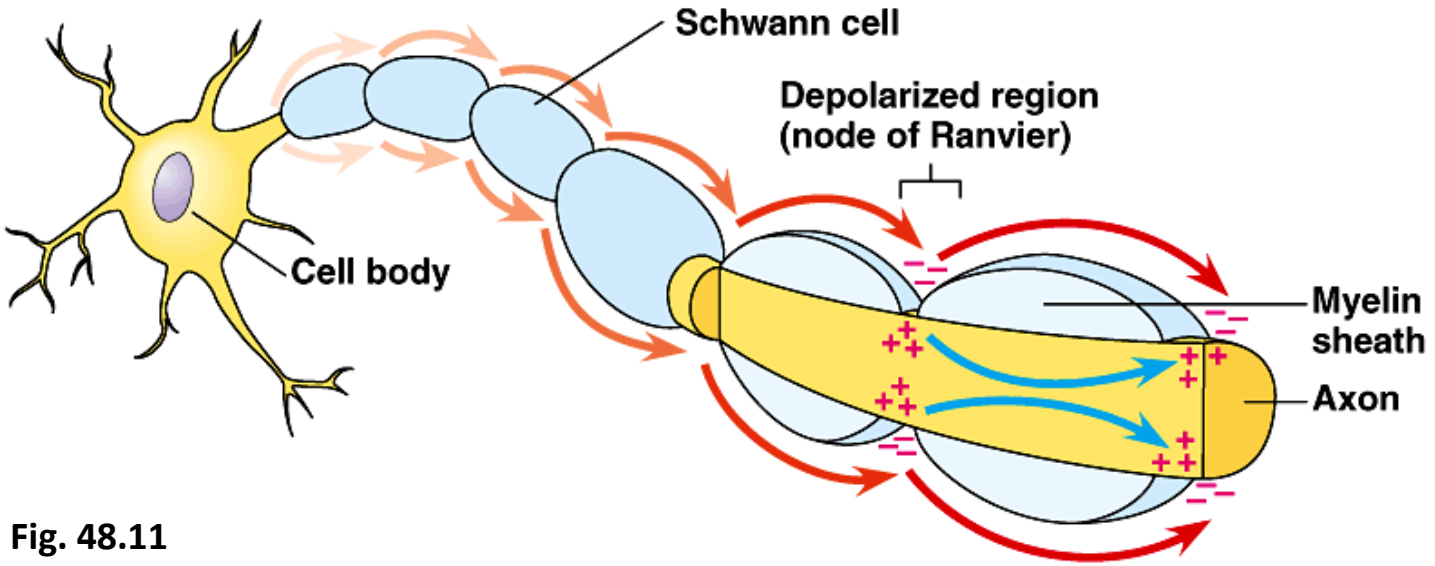


Fig. 48.11