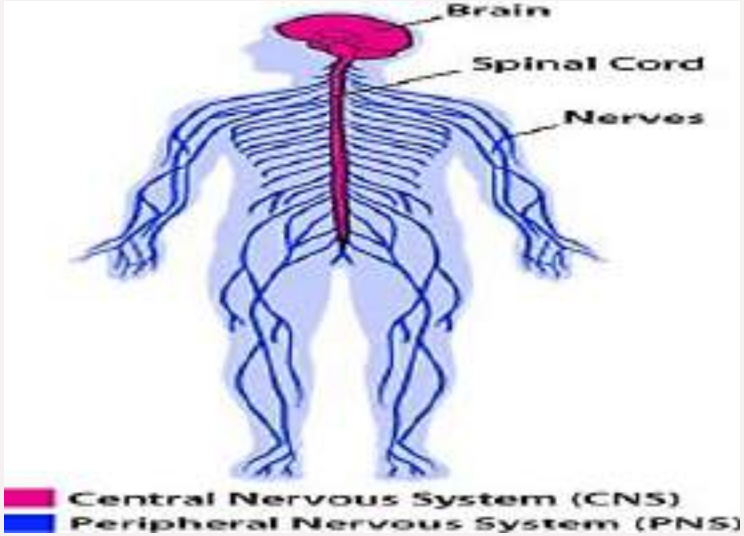
PNS MODULE
PHYSIOLOGY (LECTURE 1)
PHYSIOLOGY OF PERIPHERAL NERVOUS SYSTEM



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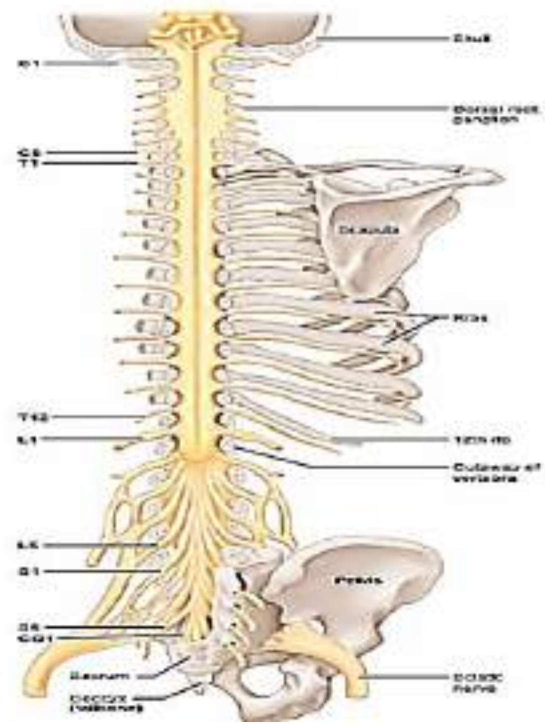
Organization and General Functions of the Nervous System

- **The nervous system consists of the central nervous system (CNS) and the peripheral nervous system (PNS).**
- The CNS includes the brain and spinal cord.
- **The PNS includes nerves, ganglia, and sensory receptors outside the CNS.**
- **The PNS has 43 pairs of nerves: 12 pairs of cranial nerves attached to brain and brain stem and 31 pairs of spinal nerves ; one pair attached to each spinal cord segment.**



THE PERIPHERAL NERVOUS SYSTEM (PNS)

The PNS is the portion of the nervous system that lies beyond the brain and spinal cord.

- **The PNS can be subdivided into sensory and motor systems:**
- ✓ **Sensory system: Sensory nerves that transmit information from various sensory receptors to the CNS.**
- ✓ **Motor system: Motor nerves that transmit information from the CNS to effector tissues or organs, muscles and glands, thereby controlling their activity.**
- **The motor system consists of two subdivisions, the somatic motor system and the autonomic motor system.**

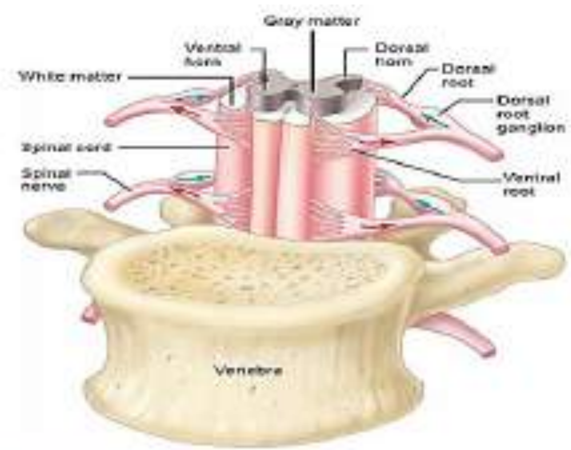


Figure 6.41 APR Section of the spinal cord, ventral view. The arrows indicate the direction of transmission of neural activity.

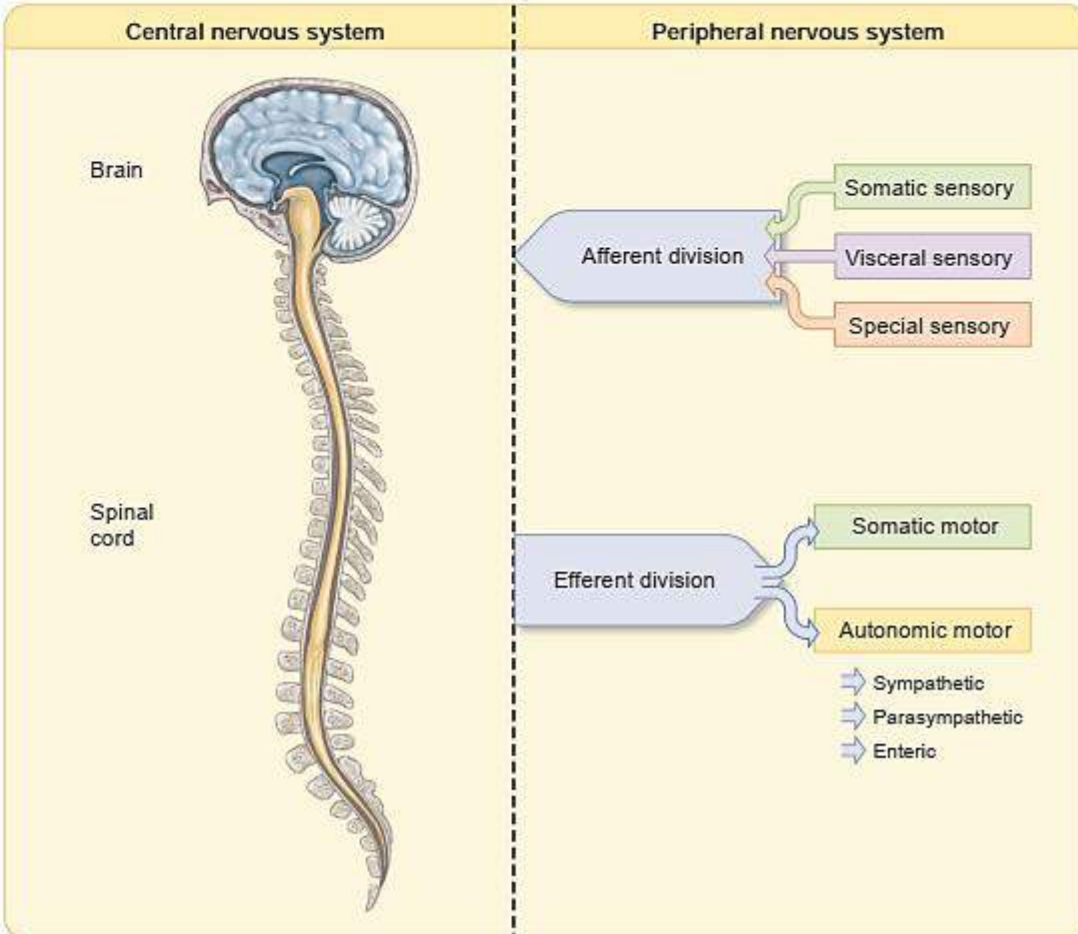


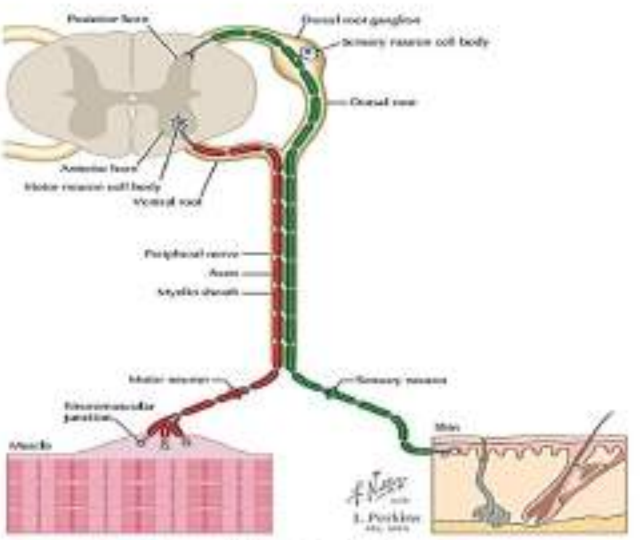
Figure 6.37 Overview of the structural and functional organization of the nervous system.

The somatic motor system:

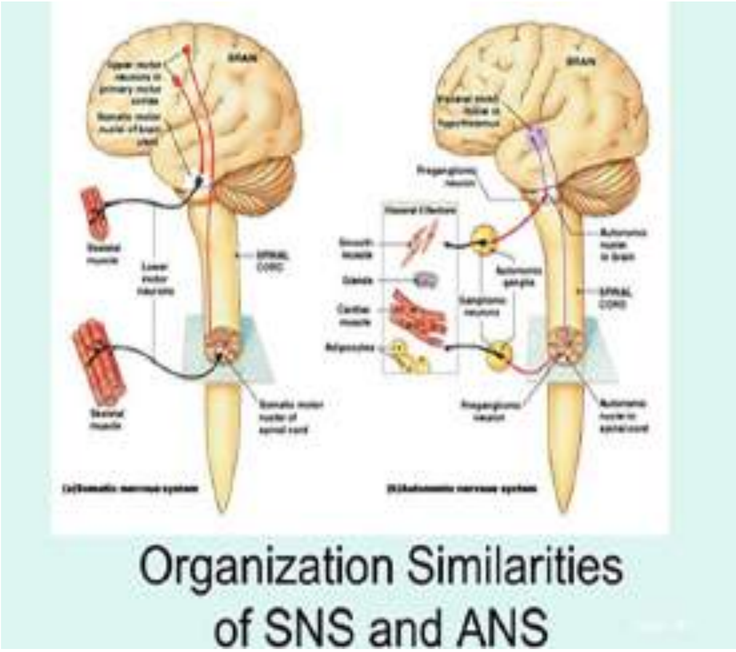
- It controls voluntary muscle activity through motor neurons and skeletal muscle.
- It arises from anterior horn cells (AHCs) of all spinal cord segments and some motor cranial nerve nuclei.

The autonomic motor system:

- It is responsible for the involuntary muscle activity (cardiac and smooth muscle contractions) and secretion of glands.
- It arises from lateral horn cells (LHCs) of some spinal cord segments and some motor cranial nerve nuclei.



Somatic Component of the Peripheral Nervous System



Peripheral Nervous System	
Somatic Division	**Autonomic Division**
o Consists of a single neuron between CNS and skeletal muscle cells	o Has two-neuron chain (connected by a synapse) between CNS and effector organ
o Innervates skeletal muscle cells	o Innervates smooth and cardiac muscle, glands, GI neurons, but not skeletal muscle cells
o Can lead only to muscle cell excitation	o Can be either excitatory or inhibitory

TABLE 6.9	Peripheral Nervous System: Somatic and Autonomic Divisions
Somatic	
Consists of a single neuron between CNS and skeletal muscle cells	
Innervates skeletal muscle cells	
Can lead only to muscle cell excitation	
Autonomic	
Has two-neuron chain (connected by a synapse) between CNS and effector organ	
Innervates smooth and cardiac muscle, glands, GI neurons, but not skeletal muscle cells	
Can be either excitatory or inhibitory	

THE NEURON

DEFINITION: BASIC WORKING UNIT OF THE NERVOUS SYSTEM.

- ✓ **The basic components of a neuron** for the prototypical **spinal motor neuron:**
- ✓ The **cell body (soma)** contains the nucleus that is the metabolic center of the neuron and stores the hereditary material or DNA.
- ✓ Neurons have **several processes called dendrites** that extend outward from the cell body and arborize extensively to aid **their role in receiving incoming signals, processing the information, and then transmitting the information to the soma of the neuron.**
- ✓ A typical neuron also has **a long fibrous axon** that **originates from a thickened area of the cell body (axon hillock).** The first portion of the axon is called the initial segment. The **axon divides into presynaptic terminals, each ending in a number of synaptic knobs that are also called terminal buttons**. **They contain granules or vesicles in which the synaptic transmitters released by the nerves are stored**.
- ✓ The axons of many neurons acquire a myelin sheath, a protein–lipid complex that is wrapped around the axon. In the PNS , myelin forms when a Schwann cell wraps its membrane around an axon. The myelin sheath envelops the axon except at the nodes of Ranvier, periodic gaps where the axon is unmyelinated.
- ✓ Based on the number of processes that emanate from their cell body, neurons can be classified as unipolar, bipolar, pseudounipolar, and multipolar.

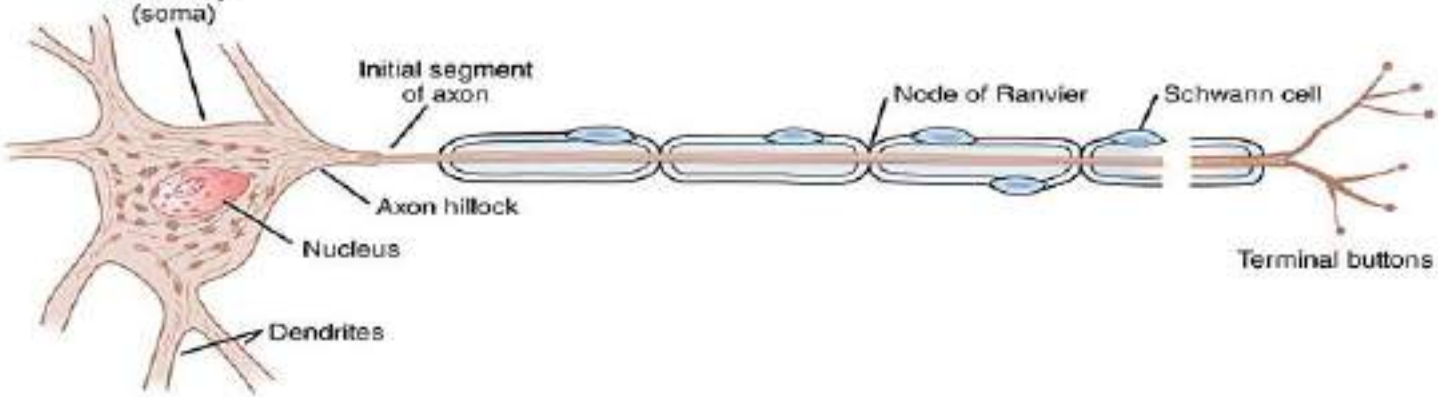


FIGURE 4–1 Motor neuron with a myelinated axon. A motor neuron is

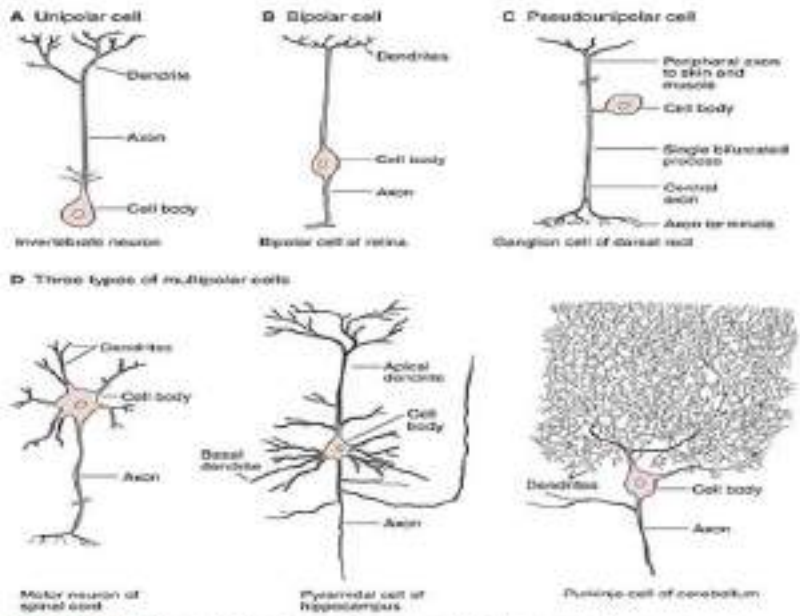


FIGURE 4–2 Some of the types of neurons in the mammalian nervous system. A) Unipolar neurons have one process, with different segments serving

EXCITATION & CONDUCTION

- ✓ **A hallmark of nerve cells (neurons) is their excitable membrane.**
- ✓ Neurons respond to electrical, chemical, or mechanical stimuli by producing **local (non-propagated) or propagated potentials** reflecting **changes in the conduction of ions across the cell membrane.**
- ✓ Depending on their location, **the non-propagated potentials are called synaptic, generator, or electrotonic potentials.**
- ✓ **The propagated action potentials are the primary electrical responses of neurons; they are the main form of communication within the nervous system.**
- ✓ **The electrical events in neurons are rapid, measured in milliseconds (ms); and the potential changes are small, measured in millivolts (mV).**
- ✓ The impulse is normally transmitted (conducted) along the axon to its termination and the impulse moves along the nerve at a constant amplitude and velocity.

RESTING MEMBRANE POTENTIAL (RMP)

- ✓ **The voltage difference across the cell membrane of a neuron is called a membrane potential**; it is the **difference between the electrical potential in the cytoplasm of the cell and the electrical potential in the extracellular space.**
- ✓ The membrane potential results from the separation of positive and negative charges across the cell membrane.
- ✓ In order for a potential difference to be present across a membrane lipid bilayer, two conditions must be met:
  - **First, there must be an unequal distribution of ions of one or more type across the membrane (ie, a concentration gradient).**
  - **Second, the membrane must be permeable to these ions. The permeability is provided by the existence of channels or pores in the bilayer**; these channels are usually permeable to a single type of ion.

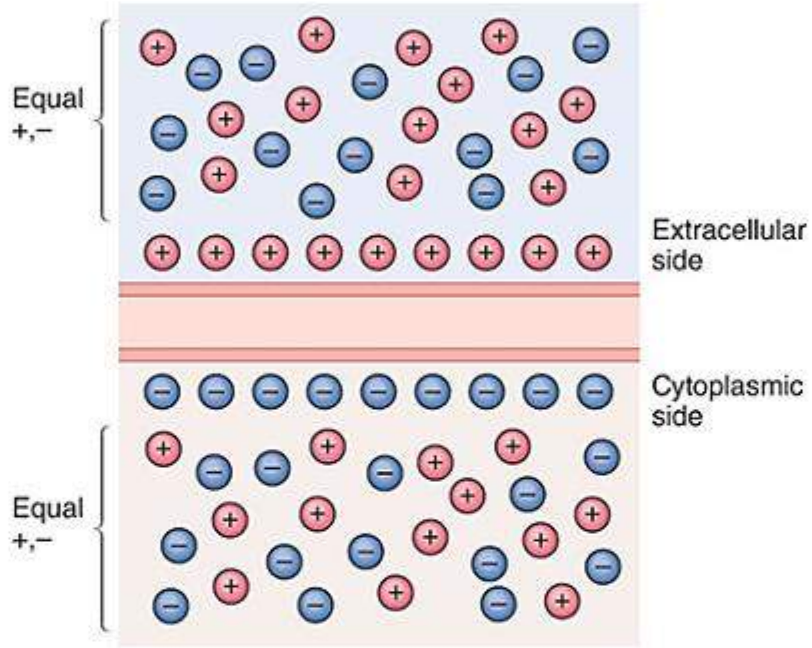


FIGURE 4–3 A membrane potential results from separation of positive and negative charges across the cell membrane. The excess of positive charges (red circles) outside the cell and negative charges (blue circles) inside the cell at rest represents a small fraction of the total number of ions present. (Reproduced with permission from Kandel ER, Schwartz JH, Jessell TM, Siegelbaum SA, Hudspeth AJ (editors): *Principles of Neural Science*, 5th ed. New York, NY:

- In neurons, the concentration of K^+ is much higher inside than outside the cell, while the reverse is the case for Na^+.
- This **concentration difference is established by Na^+- K^+ ATPase**.
- **The RMP of neurons is usually about –70 mV.**
- Because there **are more open K^+ channels than Na^+ channels at rest, the membrane permeability to K^+ is greater**. Consequently, the intracellular and extracellular K^+ concentrations are the prime determinants of the resting membrane potential.
- Steady ion leaks cannot continue forever without eventually dissipating the ion gradients. **Na^+- K^+ ATPase** prevents this from occurring by actively moving Na^+ and K^+ against their electrochemical gradients.

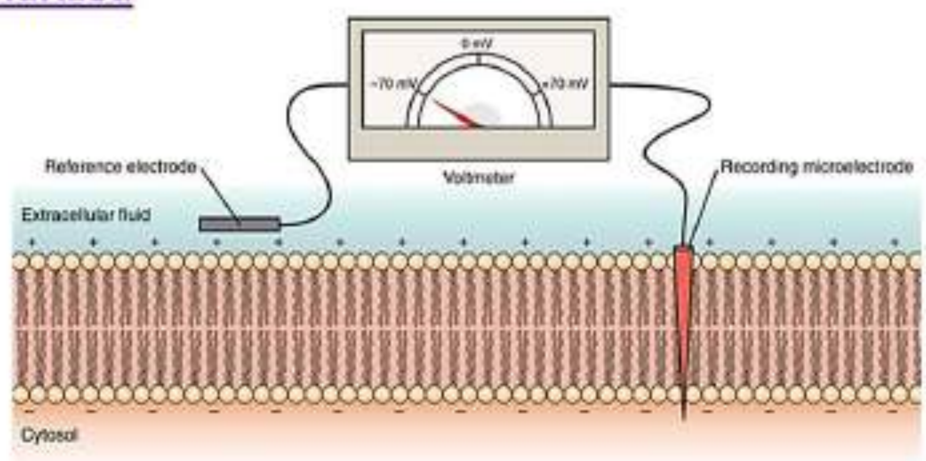
RESTING MEMBRANE POTENTIAL

الجهد الكهربائى الغشائى فى حالة عدم النشاط

DIF:- **It is a potential difference across cell membrane during rest (without stimulation)**

Value:- **-90 mV in large nerve fibers (-ve inside) (ranges between -70 mV TO -90 mV)** (the -ve or +ve sign referes to the inside of the membrane)

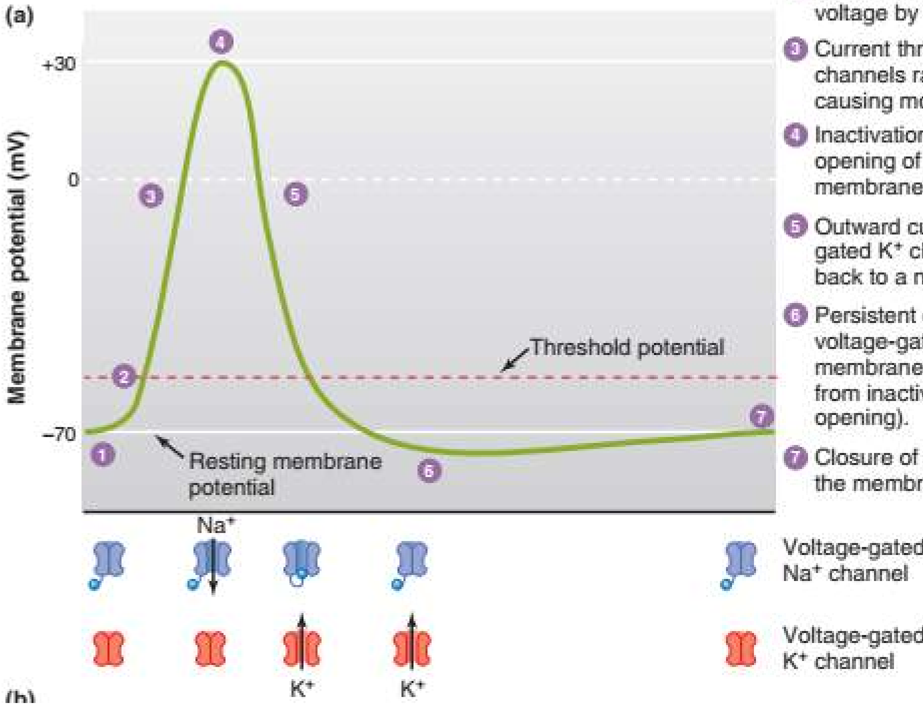
-The membrane is polarized



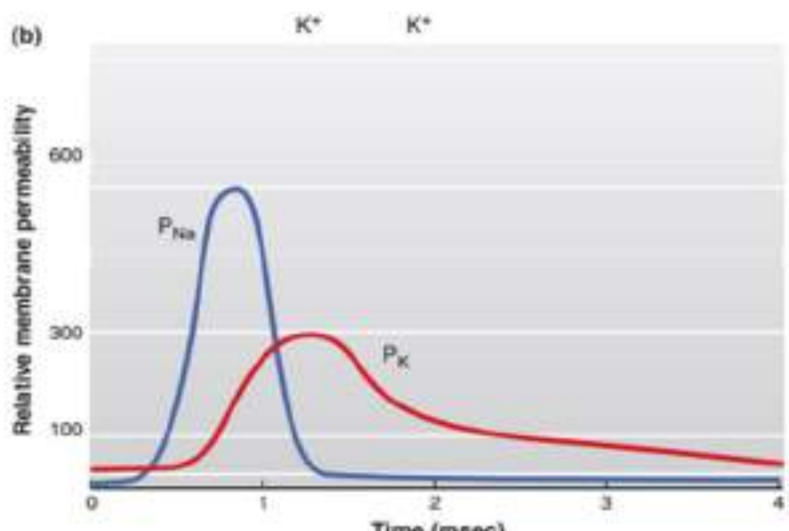
IONIC FLUXES DURING THE ACTION POTENTIAL (AP)

- An **AP begins with a depolarizing stimulus**.
- This **initial depolarization stimulates the opening of some voltage-gated Na^+ channels →** entry of Na^+ through those channels → adds to the local **membrane depolarization**.
- **The threshold of most excitable membranes is about 15 mV less negative than the resting membrane potential (RMP)**. Thus, **if the RMP of a neuron is - 70 mV, the threshold potential is - 55 mV**.
- When the **membrane reaches a critical threshold potential; Firing level (about – 55 mV)** → **depolarization becomes a positive feedback** loop→ **Na^+ entry causes depolarization** → **opens more voltage-gated Na^+ channels → more depolarization → rapid depolarization of the membrane potential.**
- **Overshoot** → **the membrane actually becomes positive on the inside and negative on the outside (+ 30 mV).**

- As the membrane potential approaches its peak value (+ 30 mV)→ Na^+ permeability is decreased as inactivation gates block the open Na^+ channels.
- Voltage-gated K^+ channels (have only one inner gate) open → elevated K^+ flux out of the cell → rapid repolarization of the membrane toward its resting value.
- The membrane returns to RMP → voltage-gated Na^+ channels go from their inactivated state back to the closed state (activation gate is closed as during RMP).
- Voltage-gated K^+ channels close relatively slowly → K^+ permeability remains above resting levels → the membrane is transiently hyperpolarized (hyperpolarization OR Undershoot).
- The voltage-gated K^+ channels finally close→ the resting membrane potential is restored.
- Whereas voltage gated Na^+ channels operate in a positive feedback mode at the beginning of an action potential, voltage-gated K^+ channels bring the action potential to an end and induce their own closing through a negative feedback process.
- Cellular accumulation of Na^+ and loss of K^+ are prevented by the continuous action of the membrane Na^+/K^+ -ATPase pumps.



1. Steady resting membrane potential is near E_K, $P_K > P_{Na}$, due to leak K^+ channels.
2. Local membrane is brought to threshold voltage by a depolarizing stimulus.
3. Current through opening voltage-gated Na^+ channels rapidly depolarizes the membrane, causing more Na^+ channels to open.
4. Inactivation of Na^+ channels and delayed opening of voltage-gated K^+ channels halt membrane depolarization.
5. Outward current through open voltage-gated K^+ channels repolarizes the membrane back to a negative potential.
6. Persistent current through slowly closing voltage-gated K^+ channels hyperpolarizes membrane toward E_K; Na^+ channels return from inactivated state to closed state (without opening).
7. Closure of voltage-gated K^+ channels returns the membrane potential to its resting value.



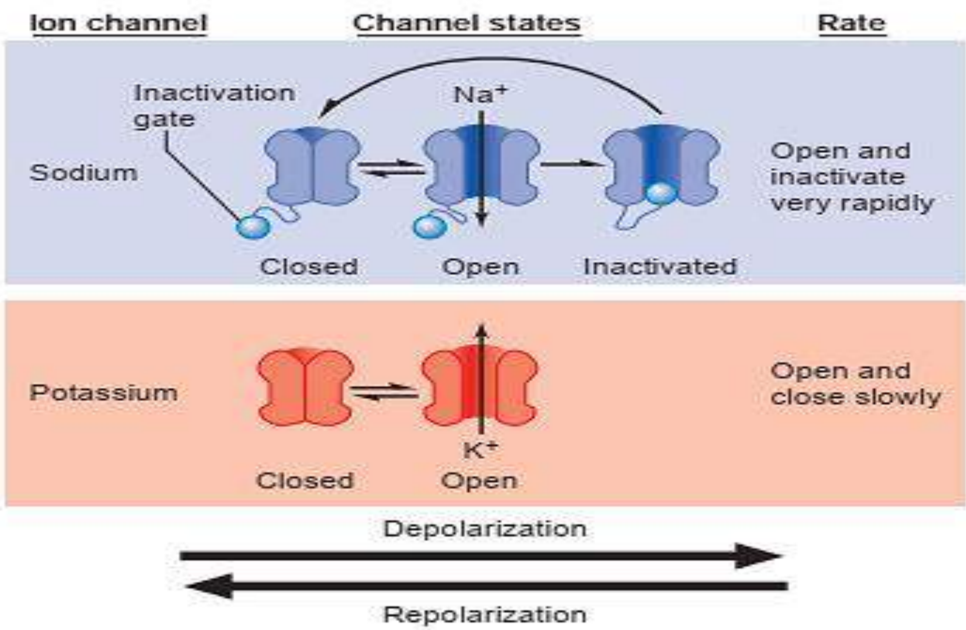


Figure 6.18 APR Behavior of voltage-gated Na^1 and K^1 channels. Depolarization of the membrane causes Na^1 channels to rapidly open, then undergo inactivation followed by the opening of K^1 channels. When the membrane repolarizes to negative voltages, both channels return to the closed state.

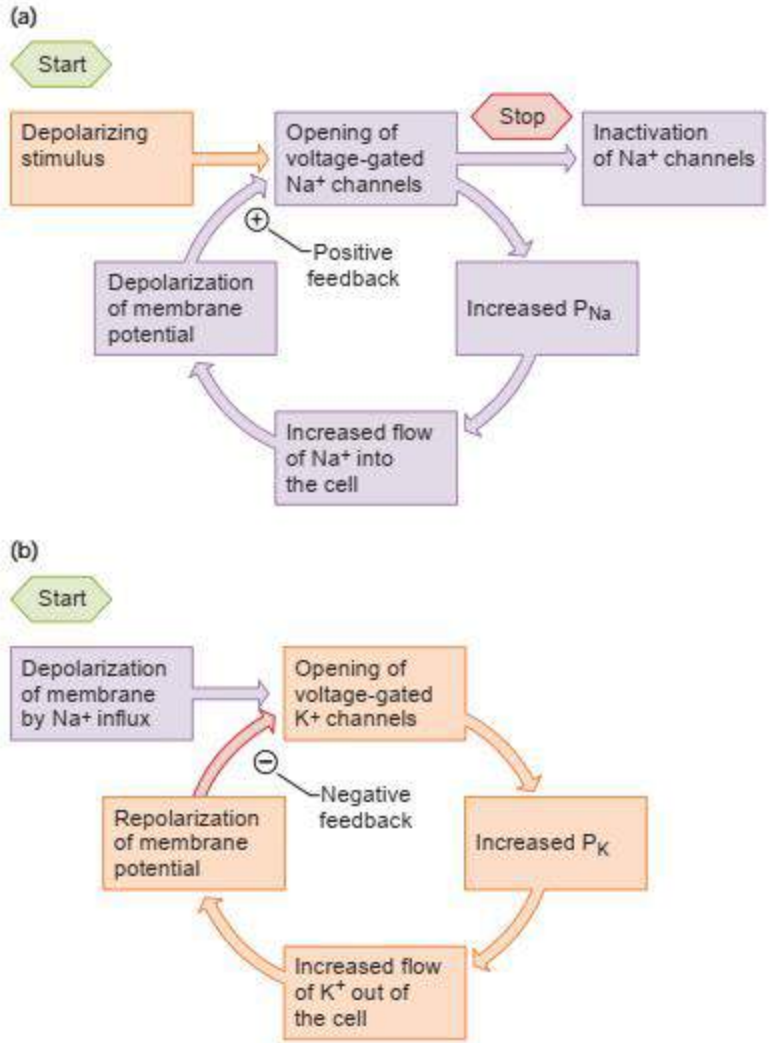
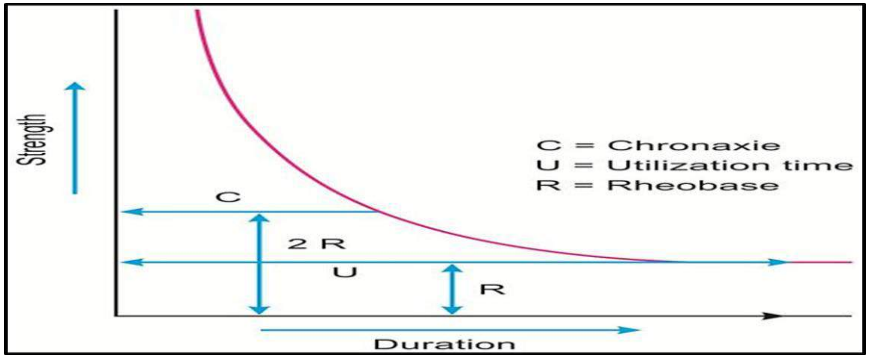


Figure 6.20 Feedback control in voltage-gated ion channels. (a) Na^1 channels exert positive feedback on membrane potential. (b) K^1 channels exert negative feedback.

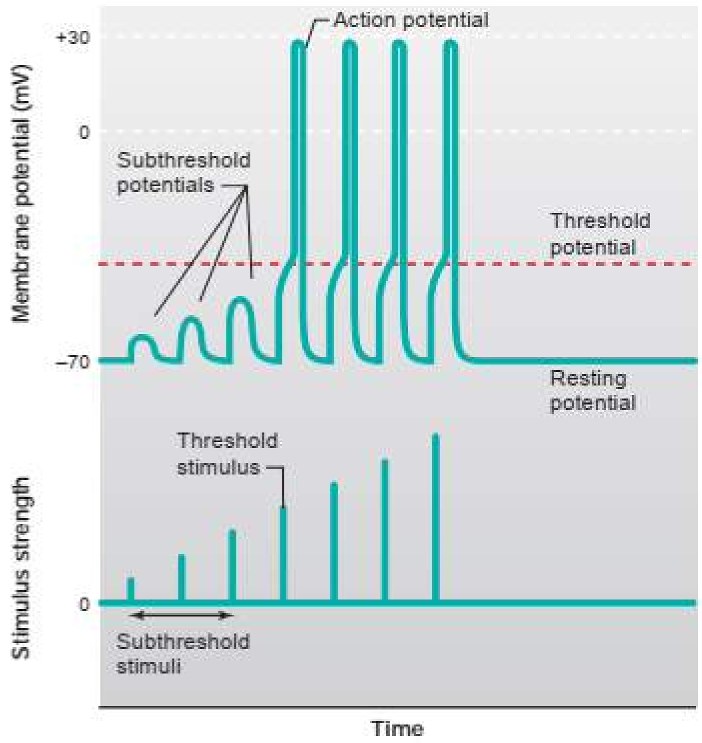
ALL-OR-NONE ACTION POTENTIALS

- **Threshold intensity: It is the minimal intensity of stimulating current needed to produce an action potential. It varies with the stimulus duration.**
- A weak stimulus needs a long duration, and a strong stimulus is sufficient at a short duration.
- **The relation between the strength and the duration of a threshold stimulus is called the strength–duration curve.**
- Slowly rising currents fail to induce an action potential in the nerve because the nerve undergoes adaptation.
- **The action potential is all-or-none in character. That is, no action potential occurs if the stimulus is subthreshold in magnitude, and the action potential has a constant amplitude and form at any stimulus strength above the threshold intensity.**

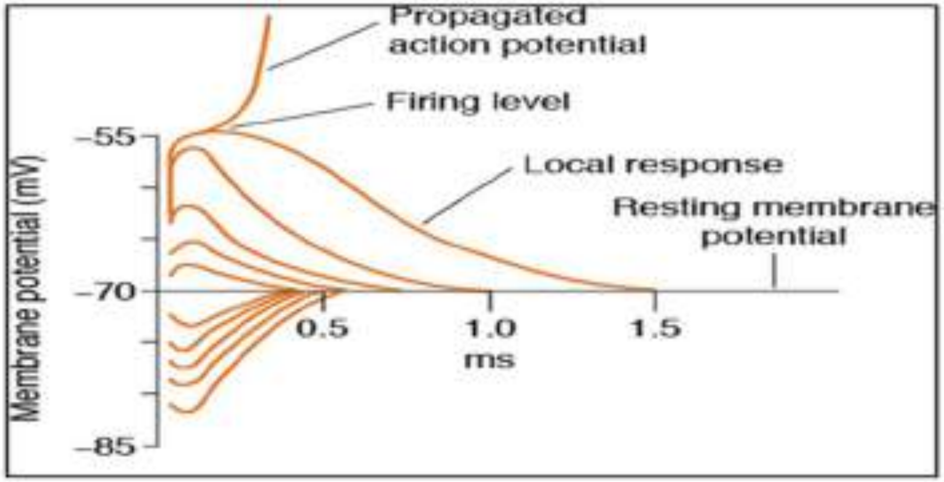


Characteristics of Action Potential

- ✓ It has a **threshold that is usually about 15 mV depolarized relative to the resting potential**.
- ✓ Depolarizations less than threshold potential → the positive feedback cycle cannot get started→ no action potential will be generated. These weak depolarizations are called **subthreshold potentials,** and the stimuli that cause them are **subthreshold stimuli.**
- ✓ Action potentials either occur maximally or they do not occur at all→ **action potentials are all-or-none.**
- ✓ **Can't be summated (fixed amplitude). Has a refractory period.**
- ✓ **Duration is constant for a given cell type under constant conditions.**
- ✓ **Mechanism depends on voltage-gated channels.**
- ✓ The **generation of action potentials is prevented** by **local anesthetics** such as **procaine** (**Novocaine**) and **lidocaine** (**Xylocaine**) because these **drugs block voltage-gated Na^+ channels, preventing them from opening in response to depolarization**.



Action potential
+30
0
-70
Membrane potential (mV)
Subthreshold potentials
Threshold potential
Resting potential
Threshold stimulus
Stimulus strength
0
Subthreshold stimuli
Time



Propagated action potential
Firing level
Local response
Resting membrane potential
-55
-70
-85
Membrane potential (mV)
0.5
1.0
1.5
ms

Excitability Changes During AP

General Rule

The **closer** is the membrane to the **threshold potential,** the **greater** is the **excitability** of the nerve (i.e. the greater the ability to produce a nerve impulse; AP).

A. Factors which decrease the nerve excitability

These factors are called **nerve stabilizers**:

1. Local anesthetics: **Block voltage-gated Na^+ channels→**decrease the permeability of the nerve membrane to Na^+→ decreases the excitability.

2. Effect of ions:

- **High Ca^{2+}** concentration in the **extracellular fluid** → decreases the permeability to Na^+ through voltage gated channels → decreases excitability.

3. Cooling, ↓blood supply, O_2 lack & acidity: ↓ excitability.

B. Factors which increase the nerve excitability

(Any condition that **increases** the permeability of the nerve membrane to Na^+ causes the nerve to be **more excitable**).

1. Warming & alkalinity → **increases** excitability.

2. Effect of ions:

- **Low Ca^{2+}** concentration in the extracellular fluid →↑ the permeability to Na^+→ ↑ excitability.

NERVE FIBER TYPES & FUNCTION

	GROUP A	GROUP B	GROUP C
Diameter	Largest diameter (3-20 microns)	Smaller diameter (1.3-3 microns)	Smallest diameter (0.3-1.3 microns)
Speed of Conduction	Highest speed (5-120 meters/second)	Moderate speed (3-15 meter/second)	Slowest speed (0.5-3 meter/second)
Examples	Somatic nerve fibers that transmit motor impulses	Myelinated preganglionic autonomic nerves	Unmyelinated postganglionic autonomic nerves
Most sensitive to	Pressure	O_2 lack (hypoxia)	Local anesthetic drugs
Subtypes	Alpha, beta, gamma and delta nerve fibers	-	-

- Although the letter classification is commonly used to describe motor fibers, a numerical system (Ia, Ib, II, III, and IV) is often used to classify sensory fibers based on their axonal diameter and conduction velocity.


THANK
YOU