Ch03: Neurophysiology

- ➔ Resting Potential
- ➔ Action Potentials
- ➔ Postsynaptic Potentials
- ➔ Synaptic Transmission
- ➔ Gross Electrical Activity

ACTION POTENTIALS

NEUROPHYSIOLOGY: study of life processes within neurons

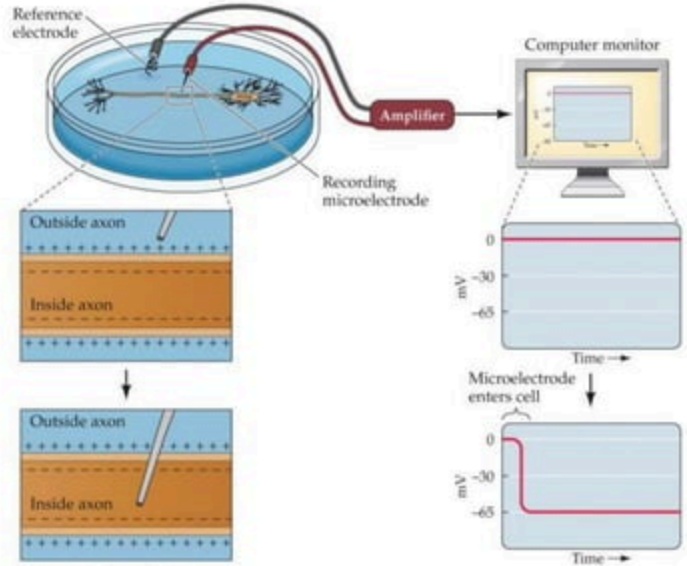
- Inside of a neuron, communication is **electrical**
  - **ACTION POTENTIAL (AP):** electrical shift that travels along the axon
- Between neurons, communication is **chemical**
  - **NEUROTRANSMITTER (NT**): chemical messengers between neurons

ACTION POTENTIALS

POLARIZED: difference in electrical charge inside & outside of the cell

RESTING POTENTIAL: stable, negative charge of an inactive neuron

-50 to -80 mV



THE MIND'S MACHINE 4e, Figure 2.1

Ch03: Neurophysiology

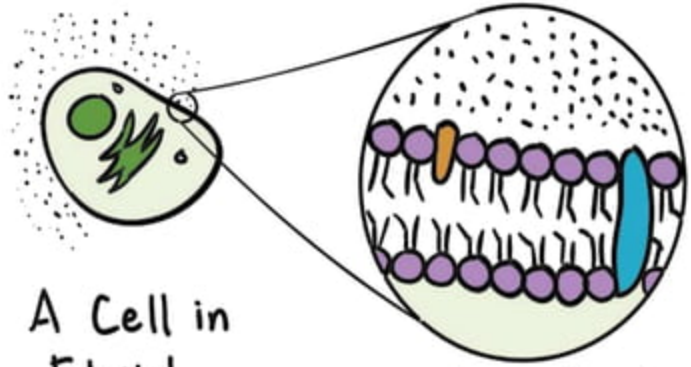
- ➔ **Resting Potential**
- ➔ Action Potentials
- ➔ Postsynaptic Potentials
- ➔ Synaptic Transmission
- ➔ Gross Electrical Activity

RESTING POTENTIAL

IONS: electrically charged molecules

- **ANIONS:** negatively charged
- **CATIONS**: positively charged

CELL MEMBRANE: lipid bilayer, outer boundary of the cell



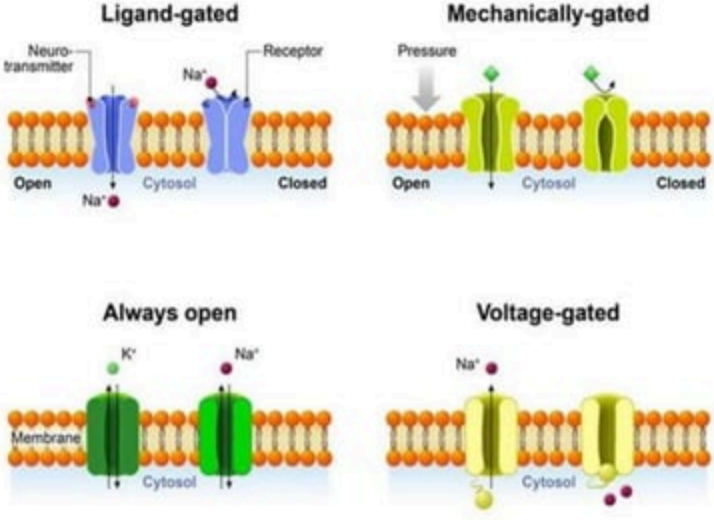
RESTING POTENTIAL

ION CHANNELS: proteins that allow ions to pass through the membrane

- Open: Potassium (K^+)
- Gated
- Sodium-Potassium Pump

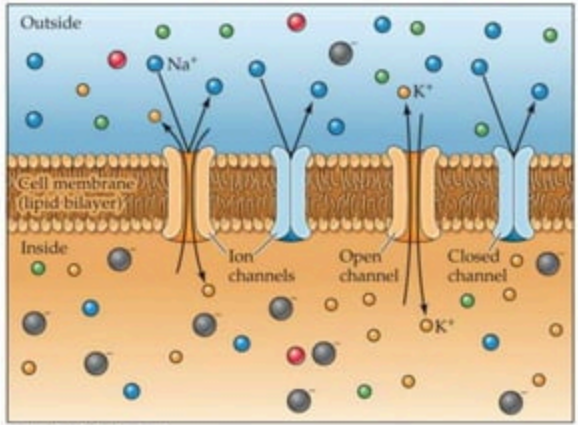
SELECTIVE PERMEABILITY: some substances can pass through (K^+), but not others

RESTING POTENTIAL



RESTING POTENTIAL

	Na^+	K^+	Cl^-	Ca^{2+}	$^-$ Proteins
Outside cell	many	few	many	many	few
Inside cell	few	many	few	few	many



THE MIND'S MACHINE 4e, Figure 2.2

RESTING POTENTIAL

Forces driving ion movement:

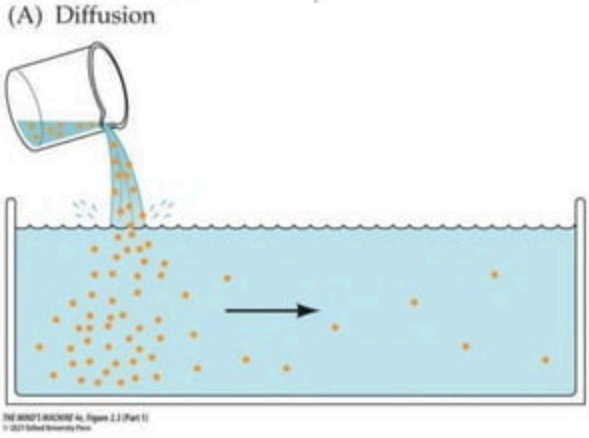
DIFFUSION: causes ions to spread towards a uniform concentration

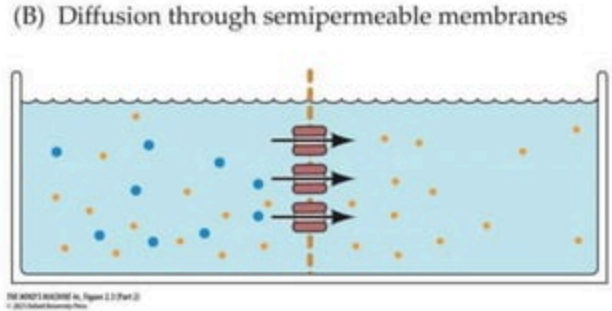
Diffusion

RESTING POTENTIAL

Forces driving ion movement:

DIFFUSION: causes ions to spread towards a uniform





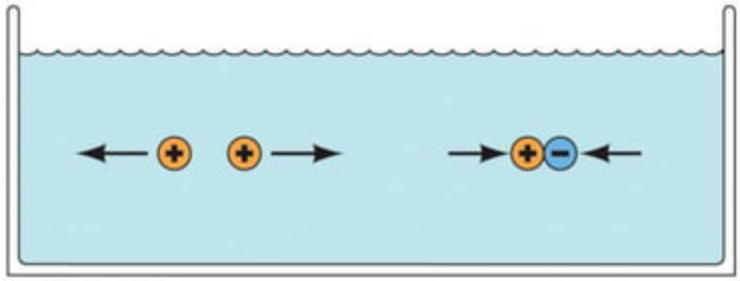
RESTING POTENTIAL

Forces driving ion movement:

DIFFUSION: causes ions to spread towards a uniform concentration

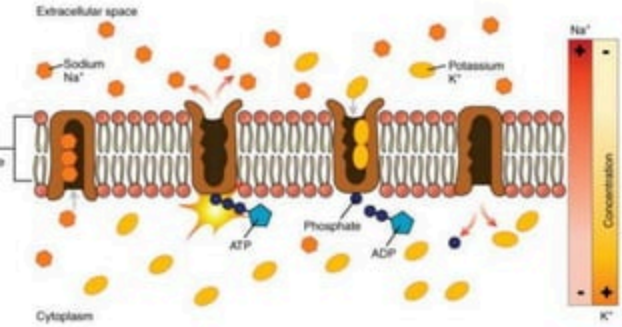
ELECTROSTATIC PRESSURE: causes ions to flow towards oppositely charged areas

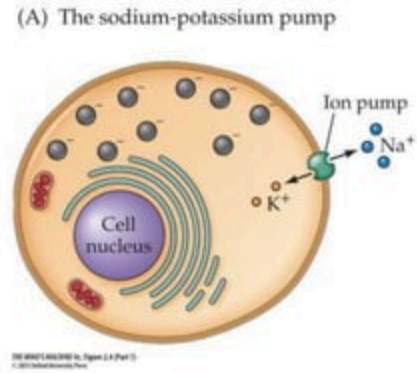
(C) Electrostatic forces



RESTING POTENTIAL

SODIUM-POTASSIUM PUMPS: pump three **sodium ions** (Na^+) out for every two K^+ ions pumped in

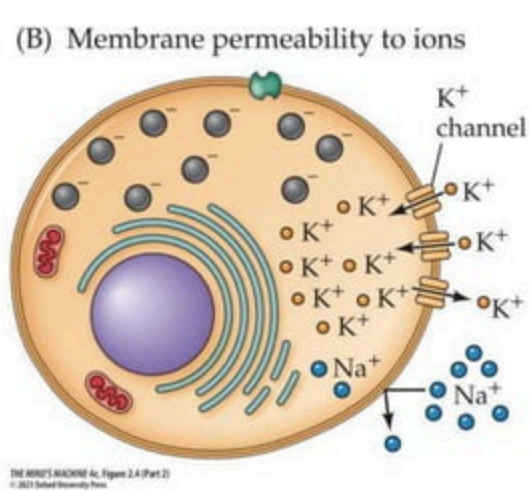




RESTING POTENTIAL

SODIUM-POTASSIUM PUMPS: pump three **sodium ions** (Na^+) out for every two K^+ ions pumped in

- As K^+ ions build up inside the cell, they also diffuse out through the open ion channels
- As negative charge builds up inside the cell it exerts electrostatic pressure to pull the K^+ ions back in

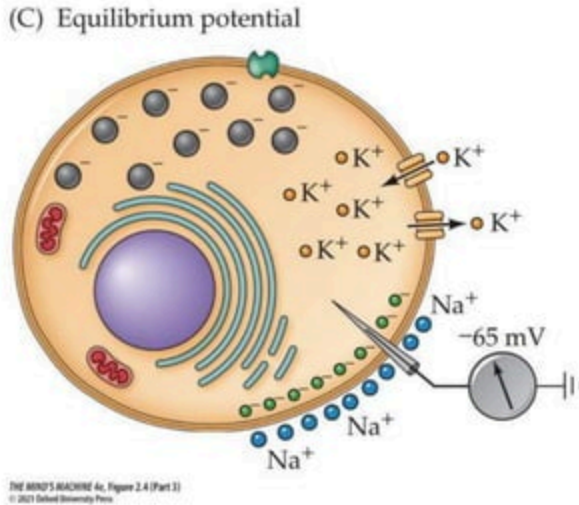


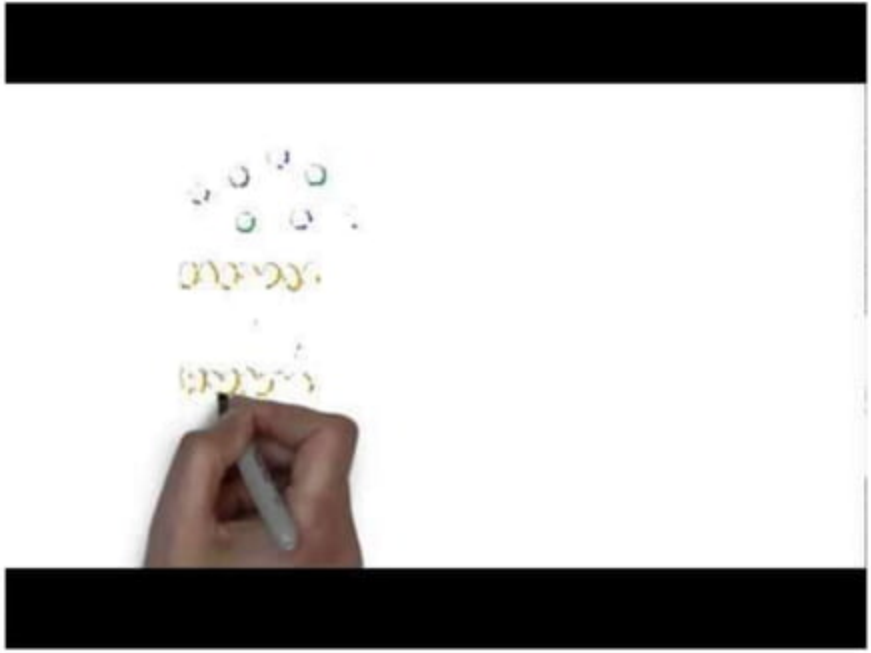
RESTING POTENTIAL

EQUILIBRIUM POTENTIAL: the electrical charge that balances diffusion & electrostatic pressure for a certain ion

- Equilibrium Potential for K^+ = ***Resting Potential***

-50 to -80 mV





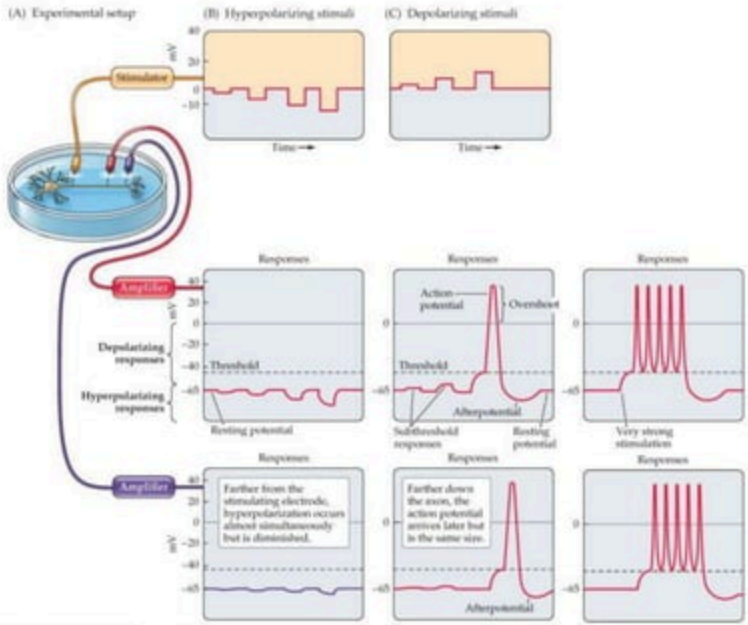
Ch03: Neurophysiology

- ➔ Resting Potential
- ➔ **Action Potentials**
- ➔ Postsynaptic Potentials
- ➔ Synaptic Transmission
- ➔ Gross Electrical Activity

ACTION POTENTIALS

- **ACTION POTENTIAL:** rapid shift in membrane potential
- **HYPERPOLARIZATION:** an increase in membrane potential; the inside becomes *even more negative*
- **DEPOLARIZATION:** a decrease in membrane potential; the inside becomes *less negative*

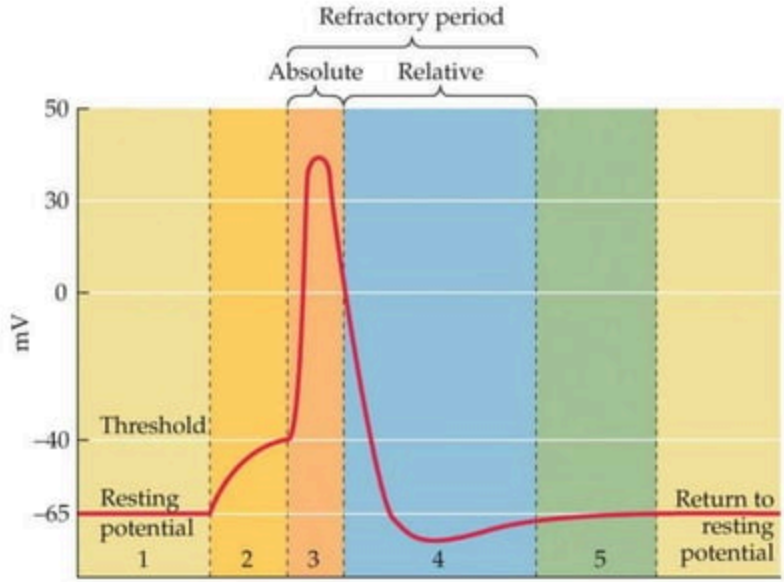
ACTION POTENTIALS



ACTION POTENTIALS

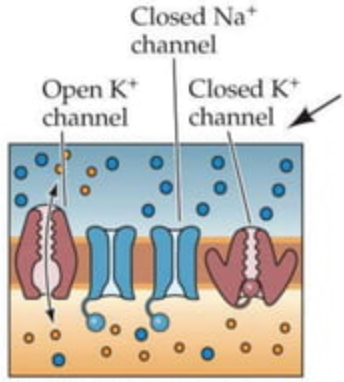
- **THRESHOLD**: the stimulus intensity needed to trigger an action potential → around -40 mV
- **ALL-OR-NONE PROPERTY**: the neuron fires at full amplitude or not at all
- **AFTERPOTENTIALS**: changes in membrane potential **after** action potentials

ACTION POTENTIALS



ACTION POTENTIALS

How an action potential is produced:

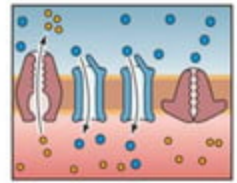


THE MIND'S MACHINE 4e, Figure 2.6

ACTION POTENTIALS

How an action potential is produced:

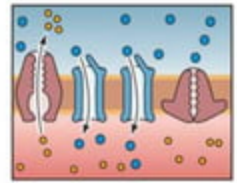
1. Voltage-gated Na^+ channels open in response to the initial depolarization



ACTION POTENTIALS

How an action potential is produced:

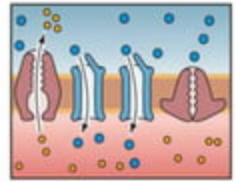
1. Voltage-gated Na^+ channels open in response to the initial depolarization
2. More voltage-gated channels open and more Na^+ ions enter



ACTION POTENTIALS

How an action potential is produced:

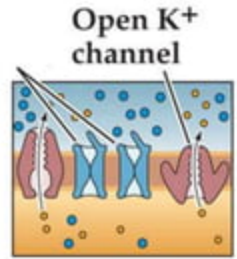
1. Voltage-gated Na^+ channels open in response to the initial depolarization
2. More voltage-gated channels open and more Na^+ ions enter
3. This continues until the membrane potential reaches the Na^+ equilibrium potential of +40 mV



ACTION POTENTIALS

How an action potential is produced:

4. As the inside of the cell becomes more positive, voltage-gated K^+ channels open

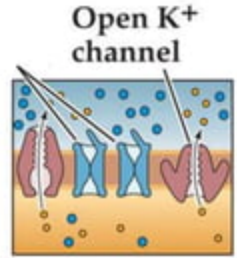


ACTION POTENTIALS

How an action potential is produced:

4. As the inside of the cell becomes more positive, voltage-gated K^+ channels open

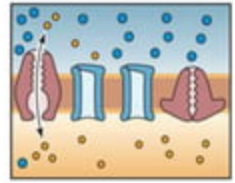
5. K^+ moves out and the resting potential is restored

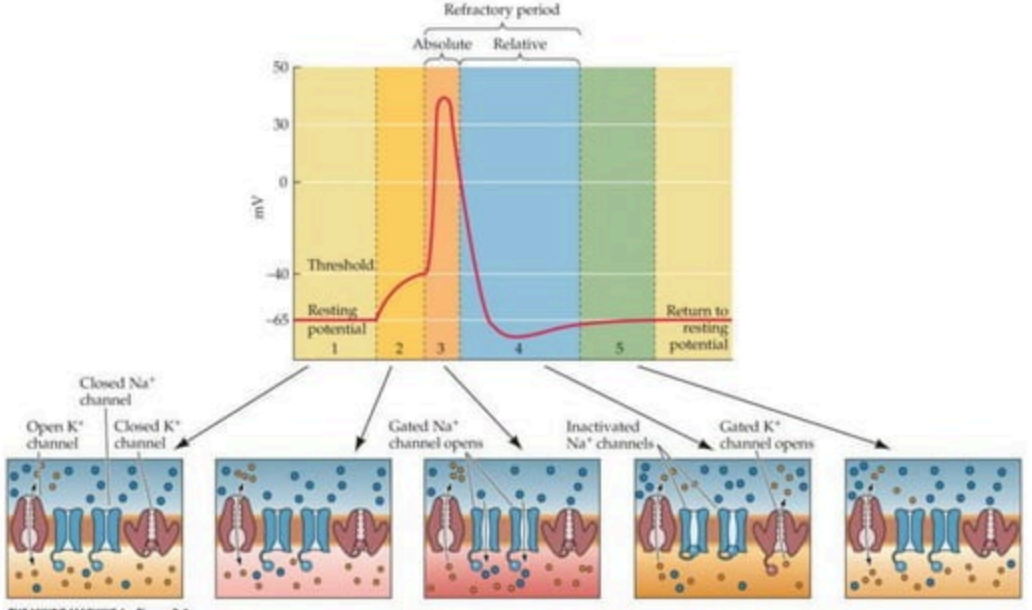


ACTION POTENTIALS

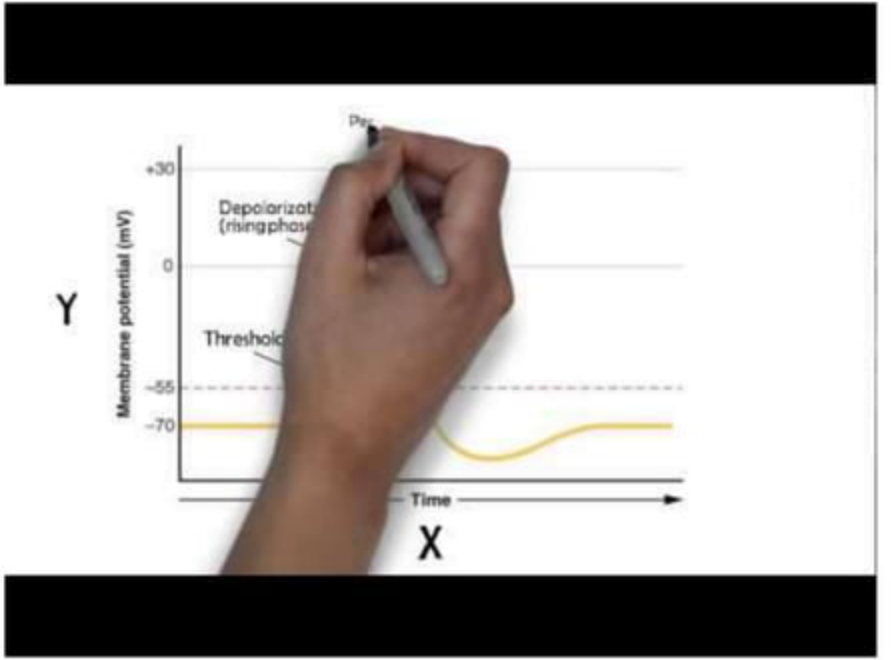
How an action potential is produced:

1. Voltage-gated Na^+ channels open in response to the initial depolarization
2. More voltage-gated channels open and more Na^+ ions enter
3. This continues until the membrane potential reaches the Na^+ equilibrium potential of +40 mV
4. As the inside of the cell becomes more positive, voltage-gated K^+ channels open
5. K^+ moves out and the resting potential is restored



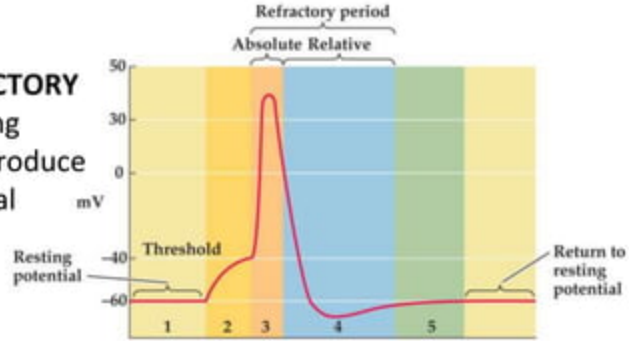


THE MIND'S MACHINE 4e, Figure 2.6

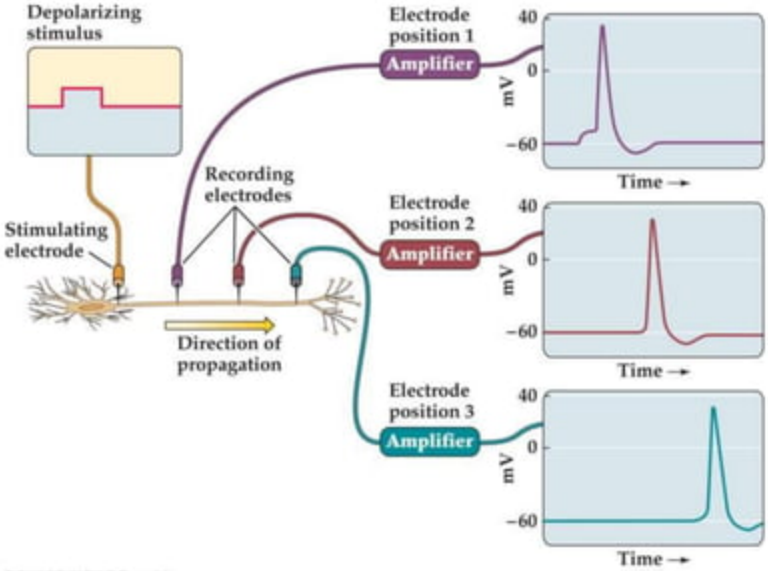

+30
0
−55
−70
Membrane potential (mV)
Time
Y
X

ACTION POTENTIALS

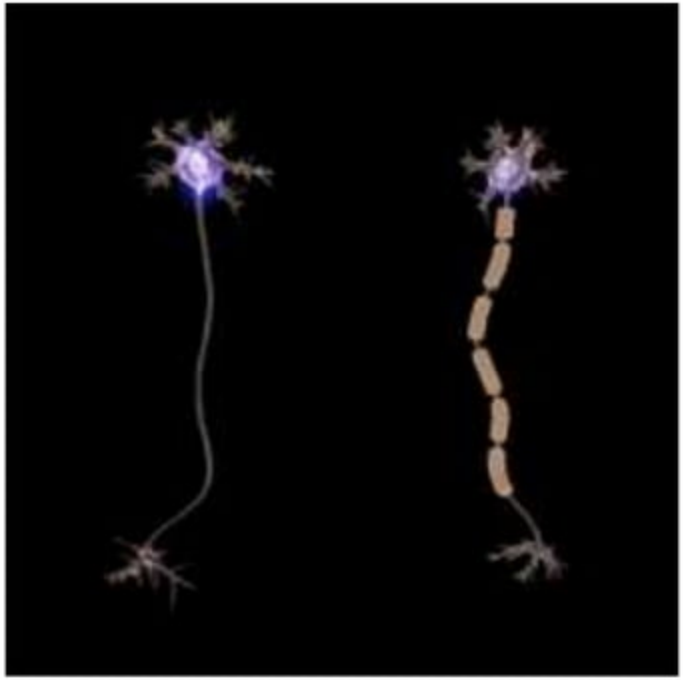
- After stimulation, the membrane becomes **REFRACTORY** (unresponsive) to later stimuli
- Two phases:
  - **ABSOLUTE REFRACTORY PHASE**: no action potentials are produced
  - **RELATIVE REFRACTORY PHASE**: only strong stimulation can produce an action potential



ACTION POTENTIALS

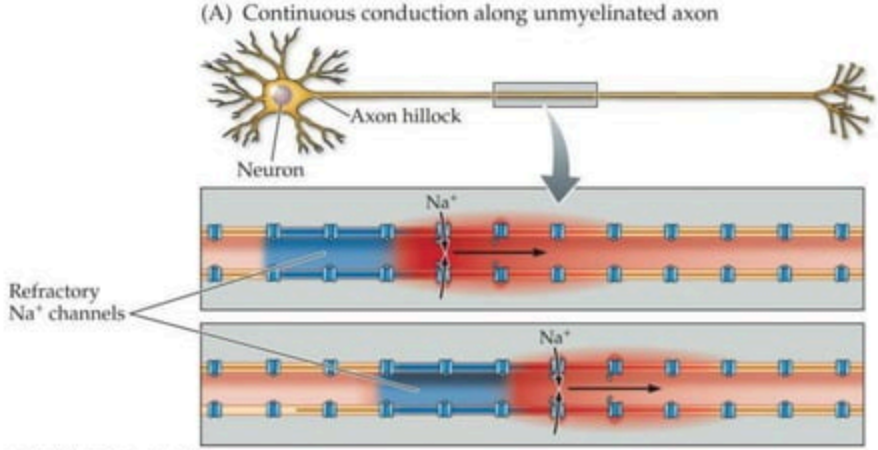


THE MIND'S MACHINE, Figure 3.7



ACTION POTENTIALS

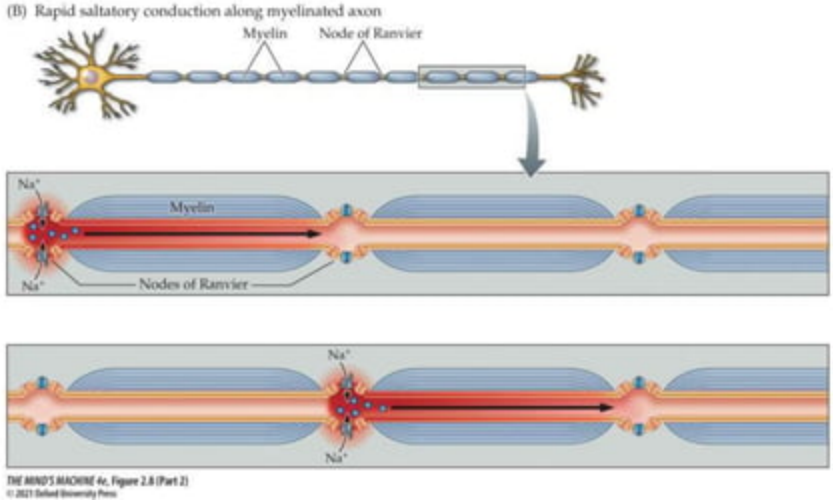
CONTINUOUS CONDUCTION: each adjacent section of axon is depolarized and a new action potential occurs



THE MIND'S MACHINE 4e, Figure 2.8 (Part 1)

ACTION POTENTIALS

SALTATORY CONDUCTION: the action potential jumps from one Node of Ranvier to the next



THE MIND'S MACHINE 4e, Figure 2.8 (Part 2)
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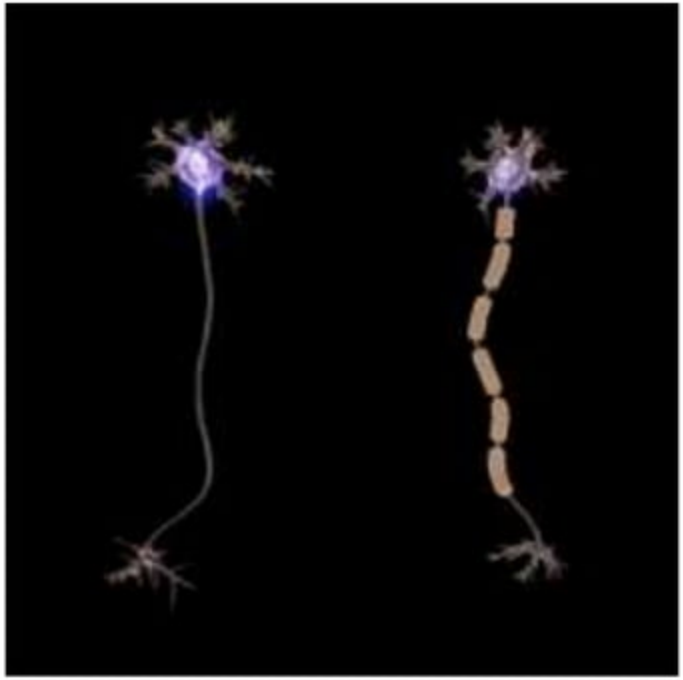


Ch03: Neurophysiology

- ➔ Resting Potentials
- ➔ Action Potentials
- ➔ **Postsynaptic Potentials**
- ➔ Synaptic Transmission
- ➔ Gross Electrical Activity

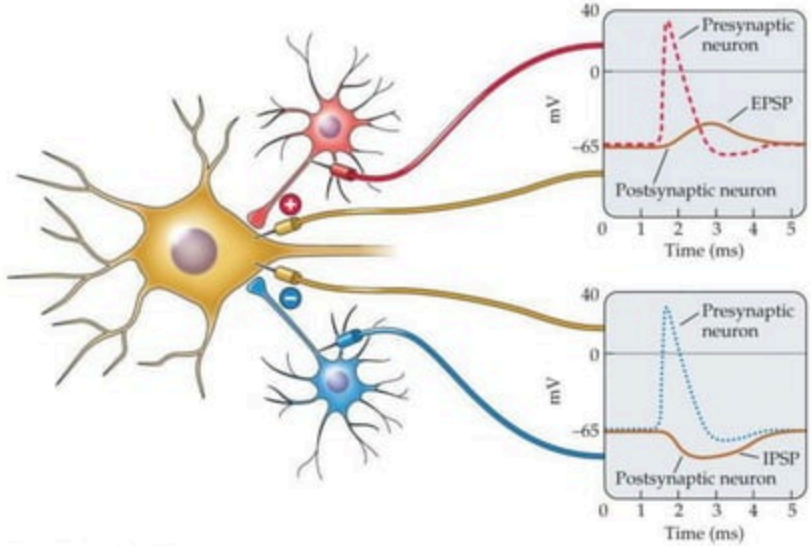
POSTSYNAPTIC POTENTIALS

POSTSYNAPTIC POTENTIALS: brief changes in the membrane potential of the postsynaptic cell in response to NT

- **EXCITATORY POSTSYNAPTIC POTENTIAL (EPSP)**: produces a small depolarization
  - **Sodium Na^+** ions enter, making the inside less negative

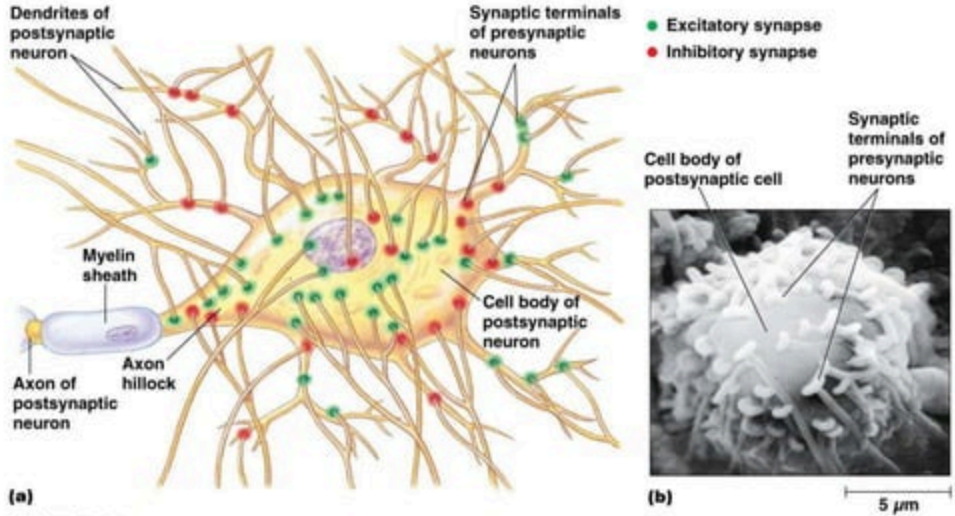
- **INHIBITORY POSTSYNAPTIC POTENTIAL (IPSP)**: produces a small hyperpolarization
  - **Chloride ions (Cl^-)** enter, making the inside more negative

POSTSYNAPTIC POTENTIALS



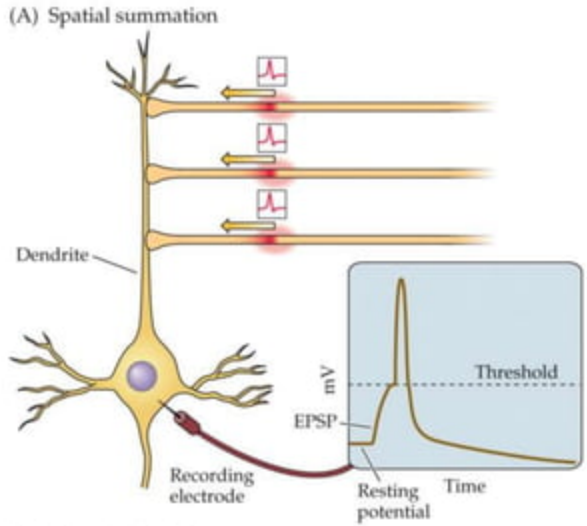
THE MIND'S MACHINE 4e, Figure 2.10

POSTSYNAPTIC POTENTIALS



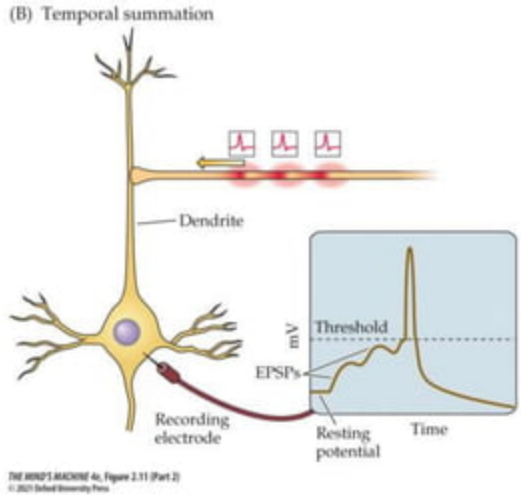
POSTSYNAPTIC POTENTIALS

SPATIAL SUMMATION: integrating inputs that come from different parts of the cell



POSTSYNAPTIC POTENTIALS

TEMPORAL SUMMATION: integrating inputs that arrive at different times



POSTSYNAPTIC POTENTIALS

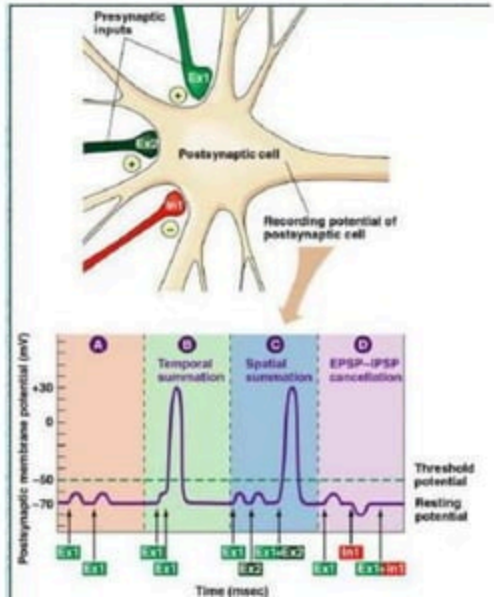


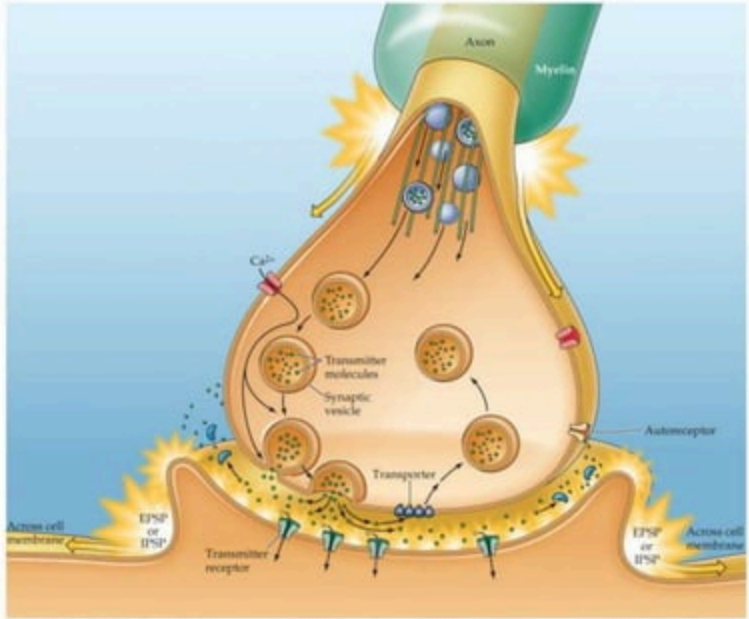
Table 2.2 Characteristics of Electrical Signals of Nerve Cells

Type of signal	Signaling role	Typical duration (ms)	Amplitude	Character	Mode of propagation	Ion channel opening	Channel sensitive to:
Action potential	Conduction along an axon	1–2	Overshooting, 100 mV	All-or-none, digital	Actively propagated, regenerative	First Na^+, then K^+, in different channels	Voltage (depolarization)
Excitatory postsynaptic potential (EPSP)	Transmission between neurons	10–100	Depolarizing, from less than 1 to more than 20 mV	Graded, analog	Local, passive spread	Na^+, K^+	Chemical (neurotransmitter)
Inhibitory postsynaptic potential (IPSP)	Transmission between neurons	10–100	Hyperpolarizing, from less than 1 to about 15 mV	Graded, analog	Local, passive spread	Cl^-, K^+	Chemical (neurotransmitter)

Ch03: Neurophysiology

- ➔ Resting Potentials
- ➔ Action Potentials
- ➔ Postsynaptic Potentials
- ➔ **Synaptic Transmission**
- ➔ Gross Electrical Activity

SYNAPTIC TRANSMISSION



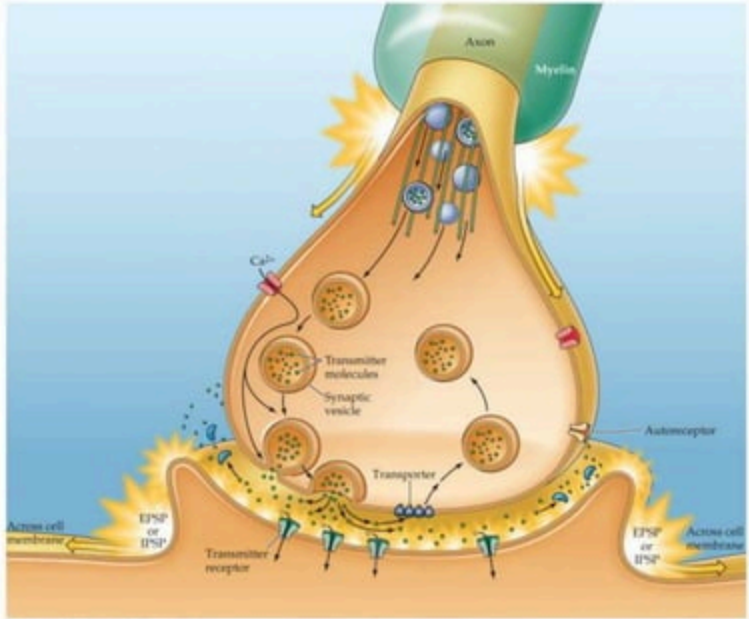
SYNAPTIC TRANSMISSION

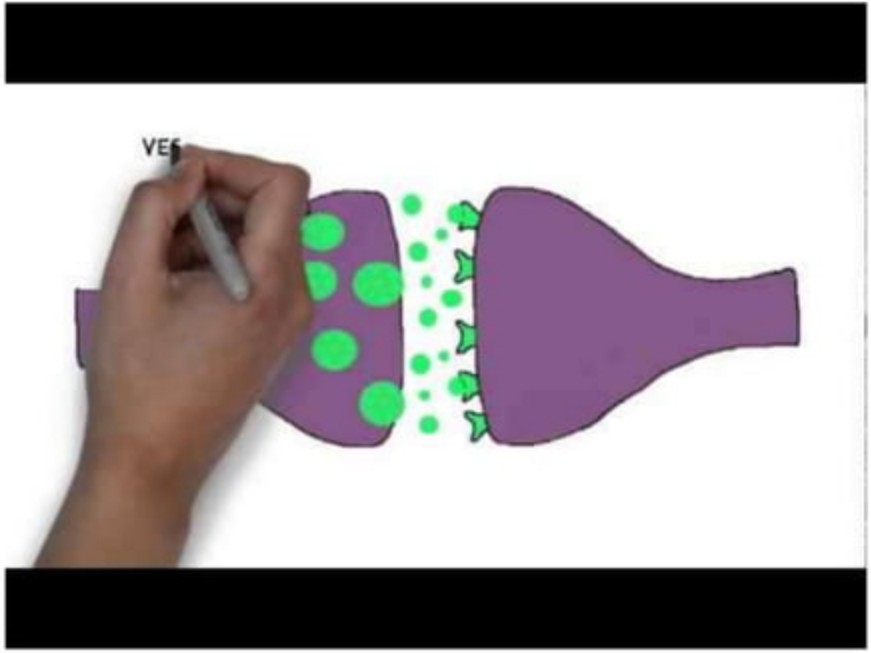
1. AP arrives at the presynaptic axon terminal
1. Voltage-gated calcium channels open & **calcium ions (Ca^{2+})** enter.
1. Synaptic vesicles fuse with membrane & release NT into the synaptic cleft.
1. NT binds to *receptor molecules* & cause an EPSP or IPSP.

SYNAPTIC TRANSMISSION

5. EPSPs or IPSPs spread toward the postsynaptic axon hillock.
6. NT is inactivated or removed – action is brief.
7. Transmitter may activate presynaptic receptors, decreasing transmitter release.

SYNAPTIC TRANSMISSION

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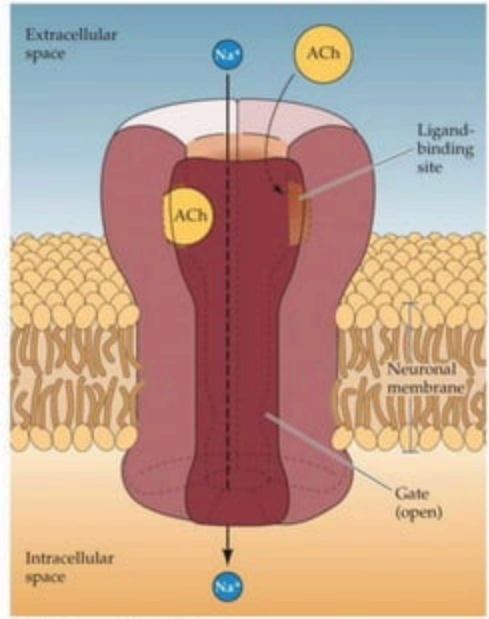
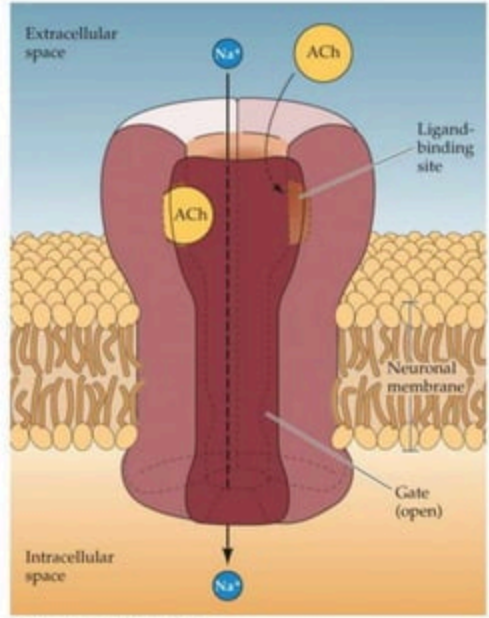
SYNAPTIC TRANSMISSION

- **LIGANDS**: molecules that fit receptors exactly and activate or block them
  - **ENDOGENOUS LIGANDS**: created inside the body
  - **EXOGENOUS LIGANDS**: introduced from outside the body



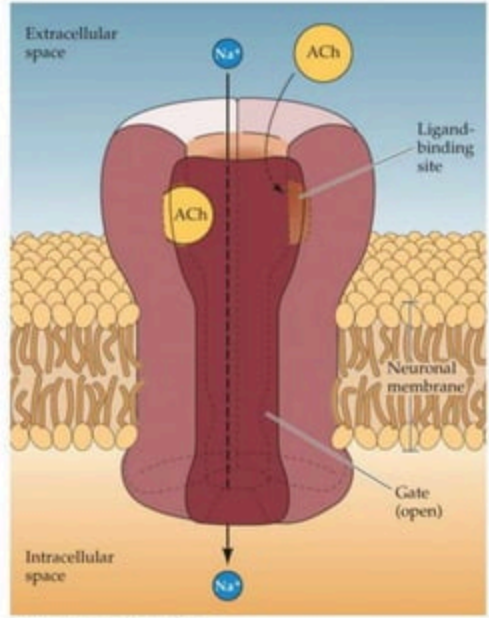
SYNAPTIC TRANSMISSION

- A synapse that uses the NT **acetylcholine** (**ACh**) has *ligand-binding sites* for ACh on **receptor molecules** in the postsynaptic membrane
  - ACh can be excitatory, and open channels for Na^+ and K^+
  - Or it can be inhibitory, and open channels for Cl^-



SYNAPTIC TRANSMISSION

- **AGONIST:** increases the effectiveness of NT
- **ANTAGONIST:** reduces the effectiveness of NT



SYNAPTIC TRANSMISSION

NT action is brief and is halted by two processes:

1. **DEGRADATION**: enzymes breakdown and inactivate NT
   - EX: **Acetylcholinesterase** (**AChE**)

2. **REUPTAKE**: presynaptic cell reabsorbs NT
   - **Transporters** bring the transmitter back inside

Ch03: Neurophysiology

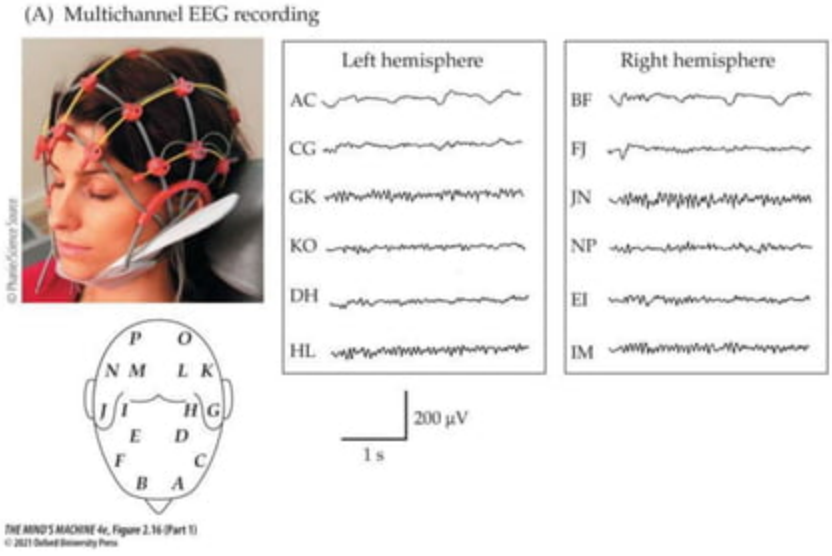
- ➔ Resting Potentials
- ➔ Action Potentials
- ➔ Postsynaptic Potentials
- ➔ Synaptic Transmission
- ➔ **Gross Electrical Activity**

GROSS ELECTRICAL ACTIVITY

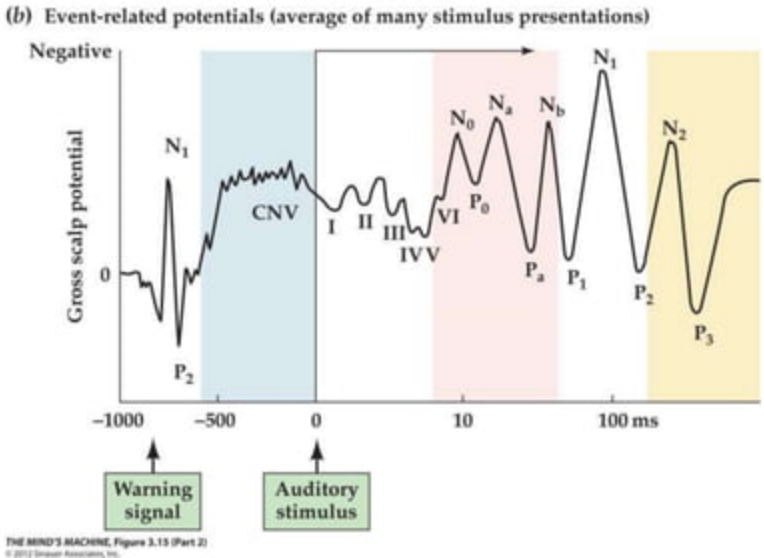
- **ELECTROENCEPHALOGRAM (EEG)**: is a recording of spontaneous brain potentials, or *brain waves*

- **EVENT-RELATED POTENTIALS (ERPs):** are EEG responses to a single stimulus, such as a flash of light or loud sound

GROSS ELECTRICAL ACTIVITY



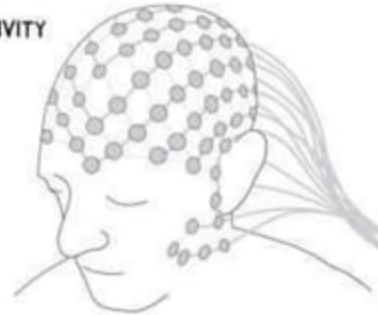
GROSS ELECTRICAL ACTIVITY



ELECTROENCEPHALOGRAPHY (EEG)

-USED TO MEASURE ELECTRICAL ACTIVITY OF THE BRAIN

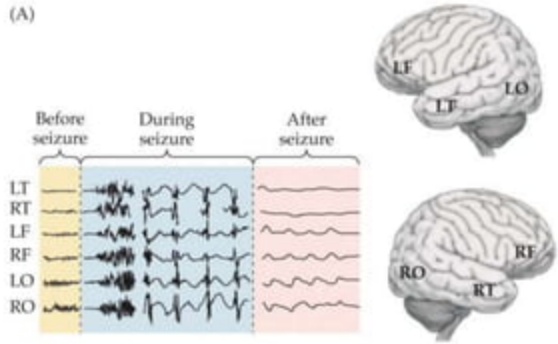
-DETECTS ACTI

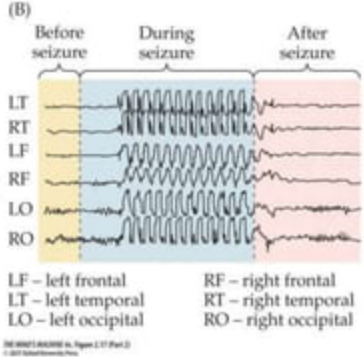


GROSS ELECTRICAL ACTIVITY

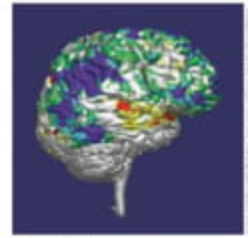
- Activity tends to be desynchronized across regions
- A symptom of **epilepsy** is **seizure**—a synchronization of electrical activity in the brain
  - **GRAND MAL SEIZURE**: abnormal EEG activity throughout the brain
  - **PETIT MAL SEIZURE**: brain waves show patterns of seizure activity for 5 to 15 seconds, can be several times a day
  - **COMPLEX PARTIAL SEIZURES**: do not involve entire brain and may be preceded by an unusual sensation, or **aura**

GROSS ELECTRICAL ACTIVITY





(C) Complex partial seizure



GROSS ELECTRICAL ACTIVITY

Hypothesis

Sensory information from the body arrives in an organized fashion in the cortex.

Experiment

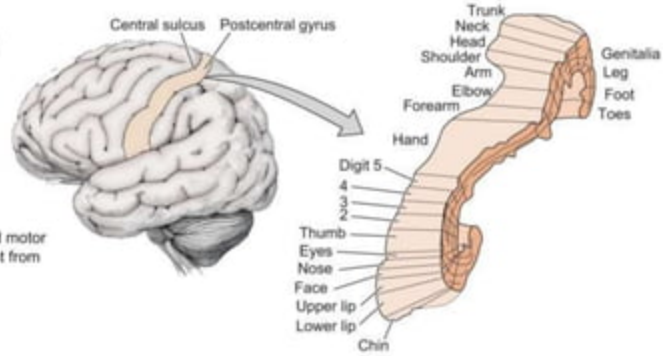
Electrically stimulate the surface of the cortex in alert patients, carefully recording the patient's experience with stimulation at each site. Compare these maps in various patients.

Result

Each side of the brain receives sensory information from the opposite side of the body, organized along the postcentral gyrus of the parietal lobe. Across the central sulcus, in the precentral gyrus, cortical regions control movement of that same part of the body so that sensory and motor regions are aligned.

Conclusion

The maps of sensory cortex and motor cortex are remarkably consistent from one person to another.



THE MIND'S MACHINE 4e, Figure 2.18