PROPAGATION OF ACTION POTENTIAL

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Physiology -2nd stage

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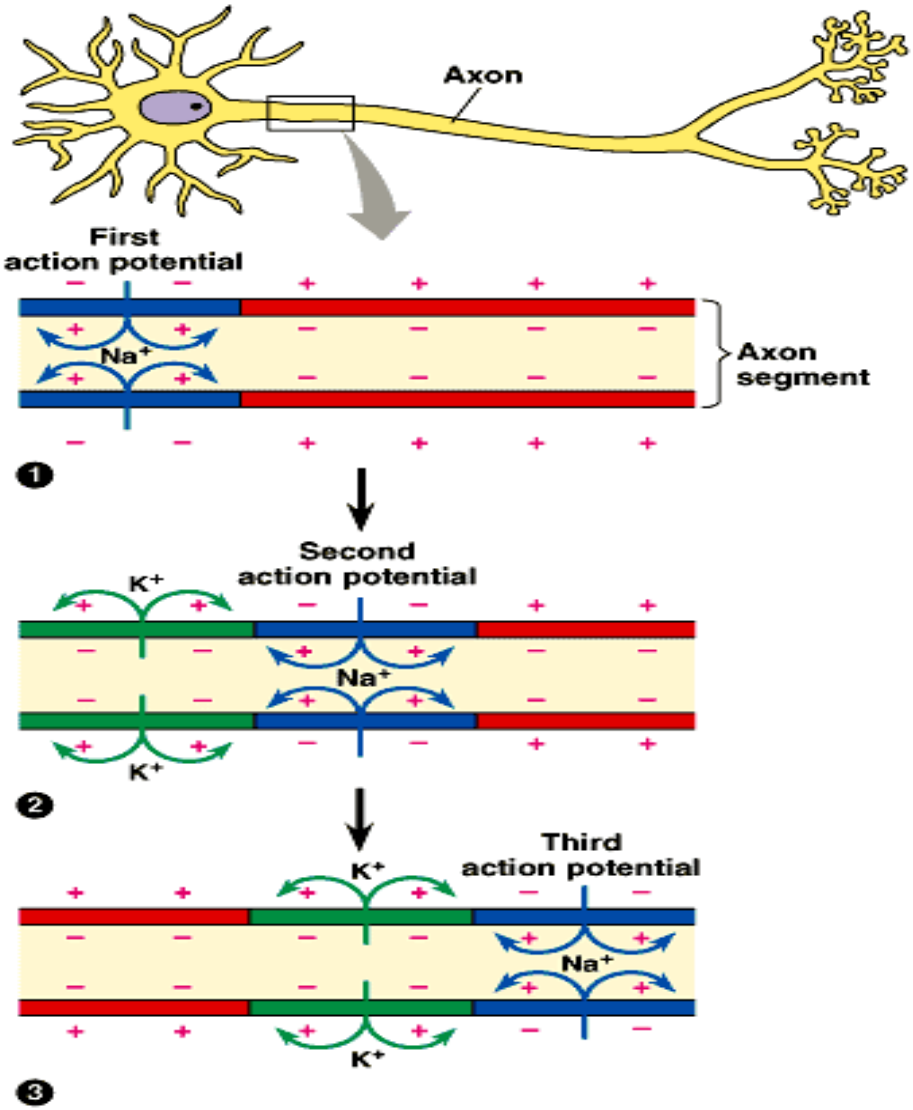
AP must be propagated (transmitted) along the entire length of the axon to serve as neuron signaling device .

*AP is generated by Na+ influx through a given area of the membrane. This influx establish local currents that depolarized the adjacent membrane area in the forward direction ..away from origin of the nerve impulse .

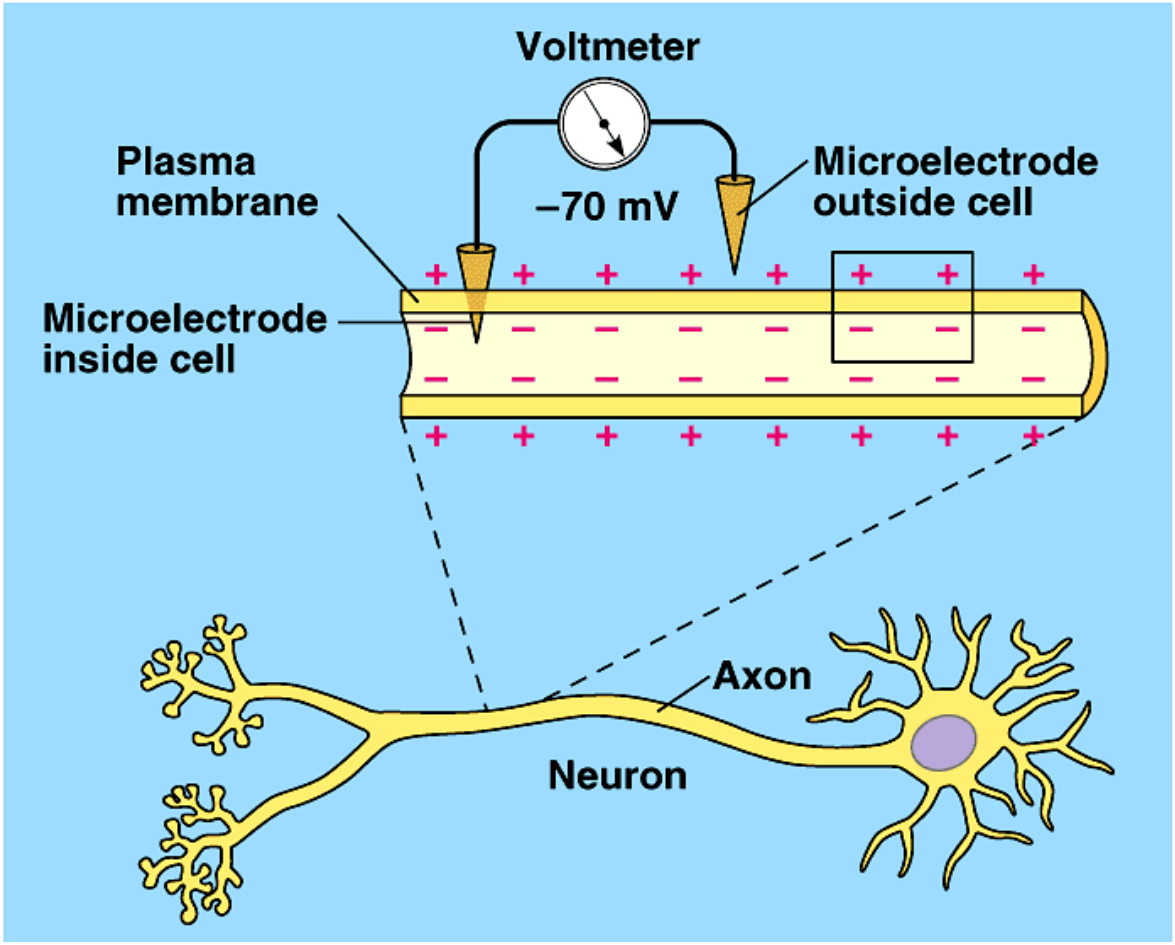
*Because the area of AP originated just generate AP, the Na+ channels in that area inactivated and no new AP generated, AP propagates away from its point of origin.

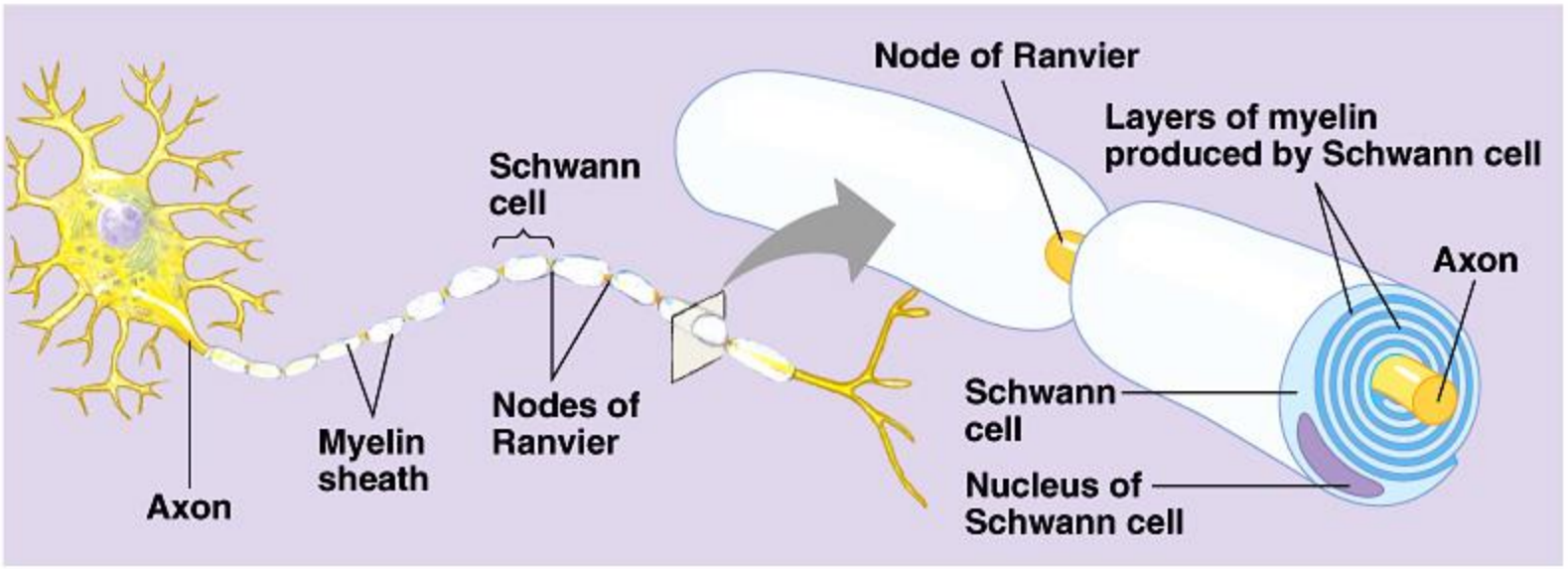

Axon
First action potential
Na+
Axon segment
1
Second action potential
K+
Na+
K+
2
Third action potential
K+
Na+
K+
3

*If isolated axon is stimulated by electrode, nerve impulse will move away from the point of stimulation in all directions along the membrane .But in the body AP initiated at one end conducted away from that point toward the axons terminals.

*Once AP initiated ,AP is self propagating and continues along the axon at a constant velocity like domino effect .This propagation process occurs on unmyelinated axon .

*Propagation process along the myelinated axon is called **Saltatory conduction .**


Voltmeter
Plasma membrane
–70 mV
Microelectrode outside cell
Microelectrode inside cell
Axon
Neuron


Node of Ranvier
Layers of myelin produced by Schwann cell
Schwann cell
Axon
Myelin sheath
Nodes of Ranvier
Schwann cell
Nucleus of Schwann cell
Axon

Properties of action potential:

1-All or none phenomenon :

Generation of AP is determined by the ability of stimulus to cause the cell to reach threshold .

If threshold reach →AP generated

If threshold is not reach →no AP

Regardless to the stimulus intensity ,AP has same amplitude .

2-Frequency :

Increased stimulus intensity lead to high frequency of AP generation .That is how can CNS determine whether a particular stimulus intense or weak! The strong stimuli cause nerve impulse to be generated more often in a given time interval than do weak stimuli. That is stimulation intensity is coded for by the number of impulse per second rather than by increase the strength (amplitude) of the individual AP.

3-Refractory period :

During refractory period the cells are unable to generate AP .Refractory period is important property of excitable cells to prevent overly rapid generation of AP ,which may cause continual contraction (tetany).

Absolute R.P: cannot be generated regardless of stimulation intensity .During the depolarization phase of AP and is due to closure Na+ channels inactivation gate.

Relative R.P :Stimulation with intensity much greater than threshold can stimulate another AP. During the repolarization phase K+ conductance is higher than in resting state ,the membrane potential is more negative.

4- Accommodation :

Cells are held in depolarization phase or depolarized very slowly , inactivation gates on Na+ channels automatically close so no Na+ current. Even if the cell has reach its normal threshold potential ,its impossible for the cell to generate another AP because few Na+ channels open .

Conduction velocity:

Conduction velocity of neurons vary widely. Nerve fibers that transmit impulses most rapidly (100m/sec) are found in neural pathway where speed essential that mediate some postural reflexes .

Axon that conduct impulse slowly serve internal organs (gut, glands ,blood vessels).The rate of impulses propagation depend largely on two factors:

1-The larger the axon diameter, the faster in conduction impulse. Because large axons offer less resistance to flow of local current.

2-Degree of myelination:

*If unmyelinated axon: in unmyelinated axon the voltage gated channels generate AP are adjacent to each other and conduction is relatively slow(***continuous conduction***).

*Myelinated axon :presence of myelin sheath lead to increase the rate of propagation ,because myelin act as insulator: prevents almost all leakage of charge from axon allowing the membrane voltage to change more rapidly .

*Current pass through the membrane of myelinated axon ***only at*** the nodes of **Ranvier** where the myelin sheath is interrupted and axon is bare and essentially all voltage gated Na+ channels are concentrated at these nodes .

*AP in myelinated fiber ,the local depolarizing current does not dissipate through the adjacent membrane region (not excitable),but the current is maintained and moves rapidly to the next node (1 mm) where it triggers another AP .So ;AP triggered only at the node .This type of conduction is called (***Saltatory conduction).***Because the electrical signal jumps from node to node along the axon .Saltatory conduction is about 30 times faster than continuous conduction .

Clinical note:

Multiple sclerosis :autoimmune disease characterized by inflammation and destruction of the myelin resulting in demyelinated fiber in CNS .It manifested in many different forms:

1-patients have cognitive changes

2-patients have paresis .

3-patients have optic neuritis

4-deperrsion

Transmission of AP between the cells:

1-Electrical transmission: rare form of AP transmission ,current travels through openings between the cells “gap junctions” in cardiac and muscles cells ,where there is cytoplasmic continuity between the constituents cells.

2-Chemical transmission: primary form by which AP are transmitted .

Synapse :clasp or join ,is a junction that mediate information transfer from one neuron to the next or from a neuron to an effectors cells –its where the action is .

Neurotransmitters are released from vesicles in the terminal bouton of the presynaptic neuron and taken up by receptors in the postsynaptic neurons.

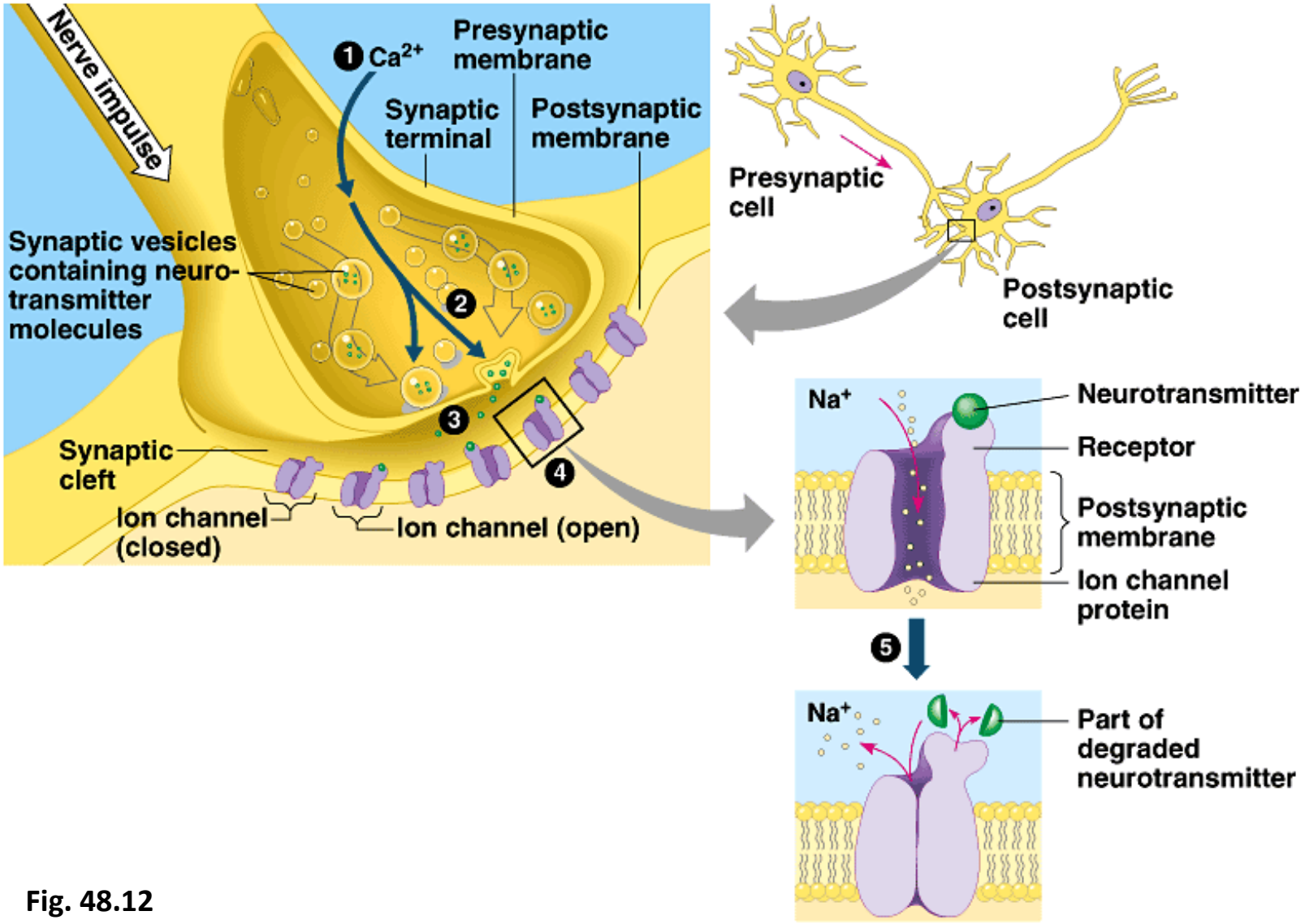


Fig. 48.12

NERVOUS SYSTEMS

The Nature Of Nerve Signals *(continued)*

4. Chemical or electrical communication between cells occurs at synapses
5. Neural integration occurs at the cellular level
6. The same neurotransmitter can produce different effects on different types of cells

4. Chemical or electrical communication between cells occurs at synapses

- Electrical Synapses.
  - Action potentials travels directly from the presynaptic to the postsynaptic cells via gap junctions.
- Chemical Synapses.
  - More common than electrical synapses.
  - Postsynaptic chemically-gated channels exist for ions such as Na^+, K^+, and Cl^-.
    - Depending on which gates open the postsynaptic neuron can depolarize or hyperpolarize.

5. Neural integration occurs at the cellular level

- **Excitatory postsynaptic potentials (EPSP)** depolarize the postsynaptic neuron.
  - The binding of neurotransmitter to postsynaptic receptors open gated channels that allow Na^+ to diffuse into and K^+ to diffuse out of the cell.
- **Inhibitory postsynaptic potential (IPSP)** hyperpolarize the postsynaptic neuron.
  - The binding of neurotransmitter to postsynaptic receptors open gated channels that allow K+ to diffuse out of the cell and/or Cl- to diffuse into the cell.

- **Summation**: graded potentials (EPSPs and IPSPs) are summed to either depolarize or hyperpolarize a postsynaptic neuron.

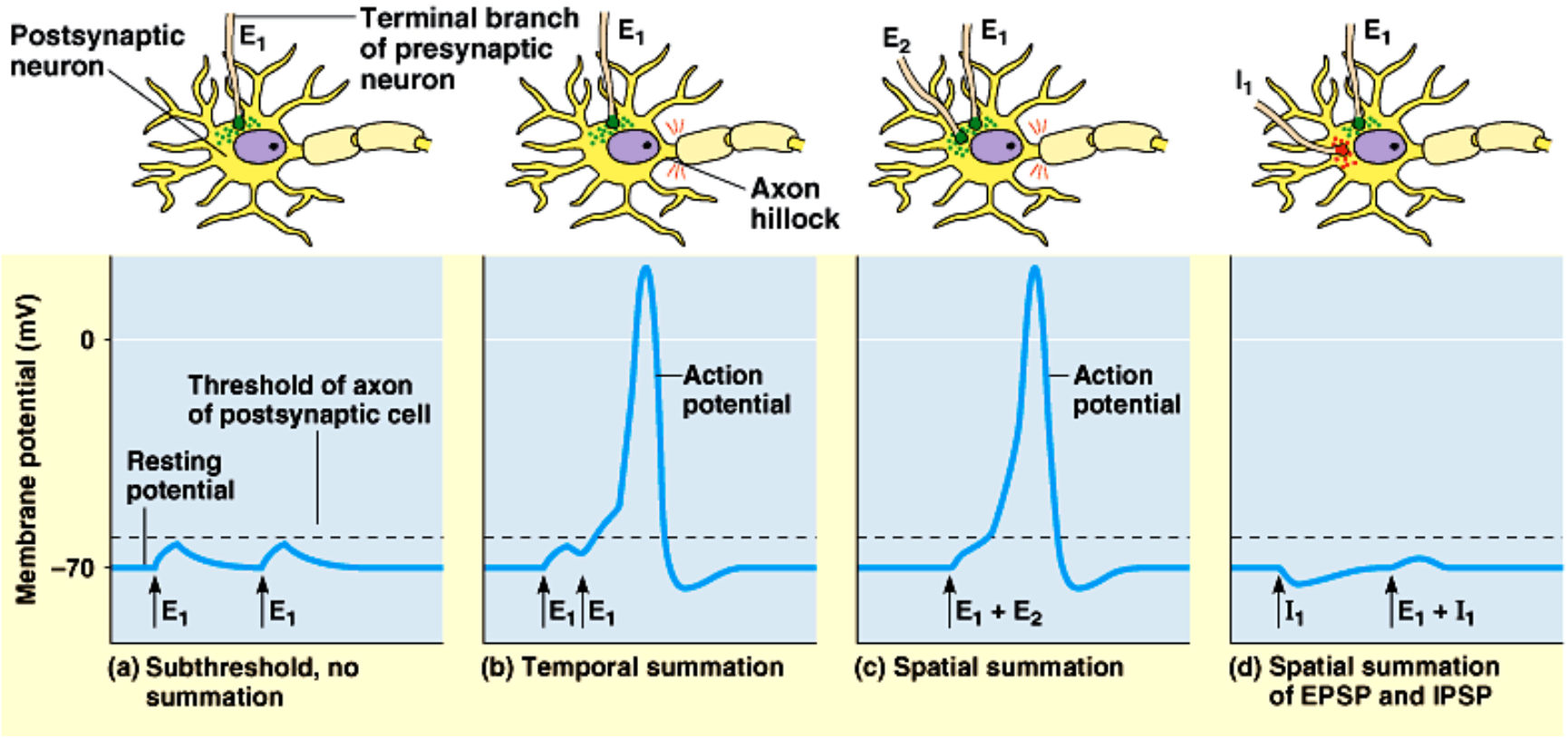


Fig. 48.14

6. The same neurotransmitter can produce different effects on different types of cells

- **Acetylcholine.**
  - Excitatory to skeletal muscle.
  - Inhibitory to cardiac muscle.
  - Secreted by the CNS, PNS, and at vertebrate neuromuscular junctions.

- **Biogenic Amines**.
  - **Epinephrine** and **norepinephrine**.
    - Can have excitatory or inhibitory effects.
    - Secreted by the CNS and PNS.
    - Secreted by the adrenal glands.

- **Dopamine**
  - Generally excitatory; may be inhibitory at some sites.
    - Widespread in the brain.
    - Affects sleep, mood, attention, and learning.
  - Secreted by the CNS and PNS.
  - A lack of dopamine in the brain is associated with Parkinson's disease.
  - Excessive dopamine is linked to schizophrenia.

- **Serotonin**.
  - Generally inhibitory.
    - Widespread in the brain.
    - Affects sleep, mood, attention, and learning
  - Secreted by the CNS.

Amino Acids

Gamma aminobutyric acid (GABA).

Inhibitory.

Secreted by the CNS and at invertebrate neuromuscular junctions.

- **Glycine.**
  - Inhibitory.
  - Secreted by the CNS.

Glutamate.

Excitatory.
Secreted by the CNS and at invertebrate neuromuscular junctions.

Aspartate.

Excitatory.
Secreted by the CNS.

- **Neuropeptides.**
  - **Substance P.**
    - Excitatory.
    - Secreted by the CNS and PNS.

Met-enkephalin (an endorphin).

Generally inhibitory.

Secreted by the CNS.

Gasses that act as local regulators.

Nitric oxide.

Carbon monoxide.