Propagation of the Action Potential

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The Action Potential

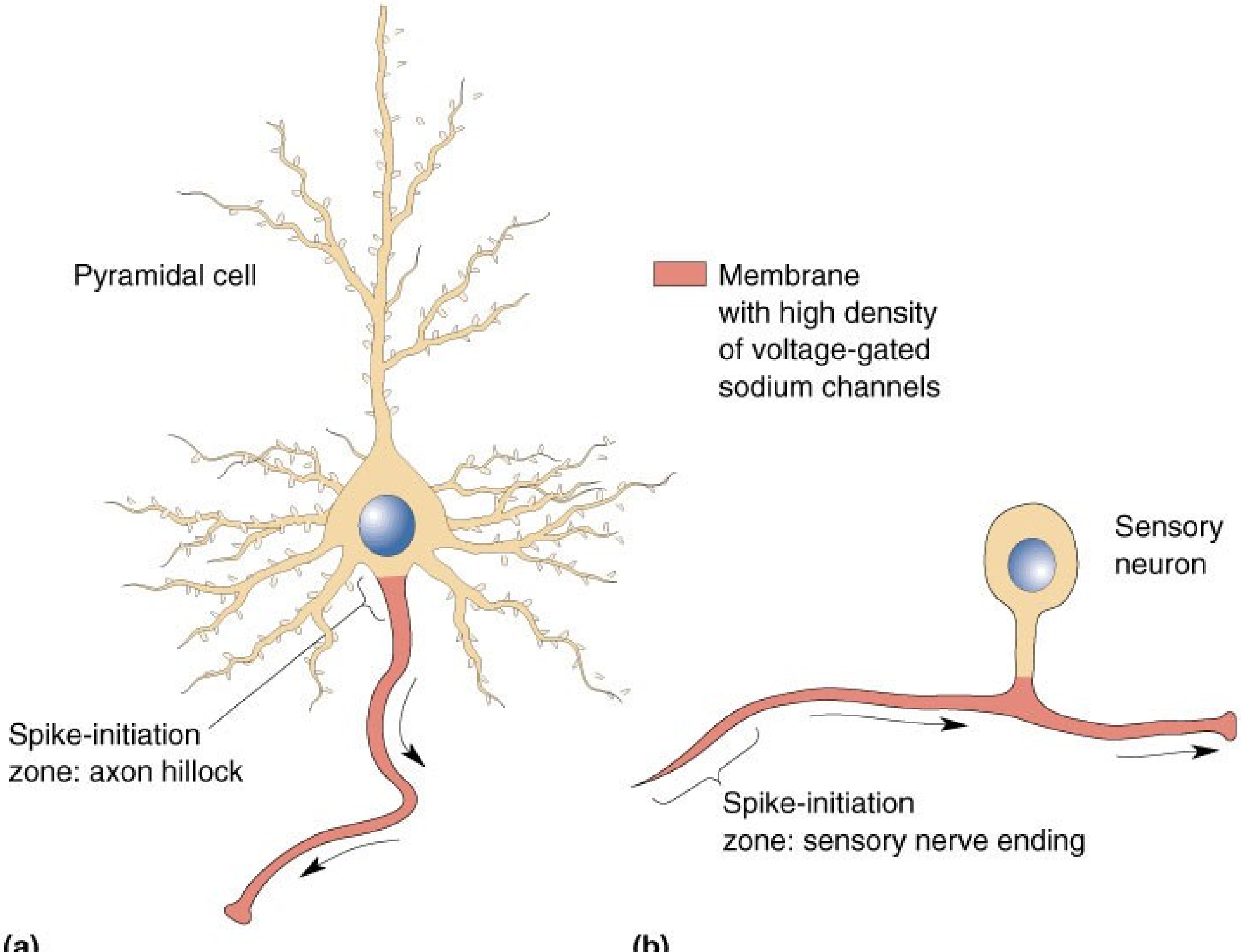
- Depolarization – influx of sodium (Na^+) or another positive ion makes the membrane potential more positive.
- When the membrane potential reaches threshold, voltage-gated Na^+ ion channels open.
- After 1 msec, voltage-gated K^+ channels open, polarizing the neuron again.
- Sodium-potassium pump helps restore neuron to its resting potential.
  - Resting potential is polarized, typically -65 mV

Voltage-Gated Channels

- Voltage-gated channels open or close with changes in the membrane potential.
- Voltage-gated sodium (Na) and potassium (K) channels coordinate the rising and falling phases of the action potential.
- The membrane of an axon contains thousands of sodium channels and the action of all of these is needed for an action potential.

Figure 4.14

Membrane proteins specify the function of different parts of the neuron. Depicted here are (a) a cortical pyramidal neuron and (b) a primary sensory neuron. Despite the diversity of neuronal structure, the axonal membrane can be identified at the molecular level by its high density of voltage-gated sodium channels. This molecular distinction enables axons to generate and conduct action potentials. The region of membrane where action potentials are normally generated is called the spike-initiation zone. The arrows indicate the normal direction of action potential propagation in these two types of neuron.

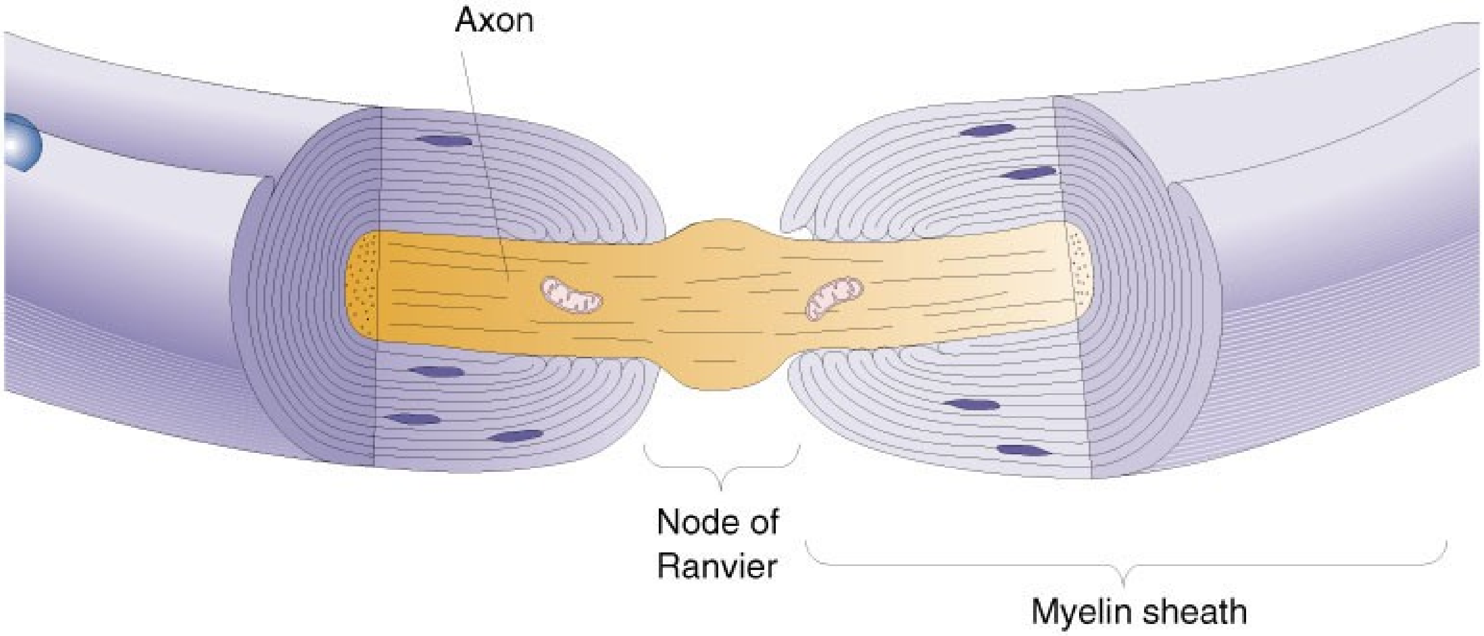


Conduction Down the Axon

- Rapid depolarization in one spot causes membrane just ahead to depolarize too.
- Speed of conduction depends on the size of the axon and the number of ion channels.
- Myelin permits the action potential to travel rapidly from node to node by blocking the membrane between nodes.
- Ion channels occur at the nodes, permitting an influx of Sodium to regenerate the action potential.

Node of Ranvier

Figure 4.12
The myelin sheath and node of Ranvier. The electrical insulation provided by myelin helps speed action potential conduction from node to node. Voltage-gated sodium channels are concentrated in the axonal membrane at the nodes of Ranvier.



Graded Response

- If action potentials are all-or-nothing and always have the same amplitude (size), how is a graded response produced?
  - More intense and longer duration stimuli produce more frequent action potentials.
  - More frequent action potentials release more neurotransmitter.
  - More neurotransmitter increases the likelihood the next neuron will have an action potential.

Interpretation of the Signals

- Action potentials are the same in neurons all over the brain.
- The meaning of an action potential comes from the interconnections among the neurons, not from the action potential itself.
  - It is the flow of information through a network that is important -- what is connected to what.
  - Connectionist models try to simulate this approach using computer software.

Differences Among Neurons

- Some local interneurons do not generate action potentials because their axons are short.
- Some neurons do not have a steady resting potential and are spontaneously active.
- Neurons differ in the types and combinations of ion channels in their cell membranes.
- Neurons differ in their neurotransmitters released and their receptors for transmitters.

Two Kinds of Neural Activity

- Excitatory – causes another neuron to be more likely to fire (have an action potential).
- Inhibitory – causes another neuron to become hyperpolarized (more negatively charged), making it less likely to fire.
  - Feed forward inhibition suppresses activity of other, opposing pathways.
  - Feed backward inhibition provides self-regulation by dampening the activity of the current pathway.

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