Ion Channels

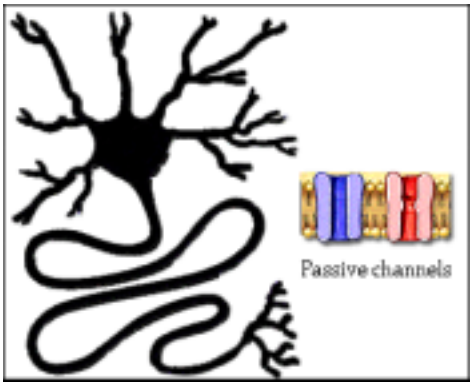
Page 1. Introduction

- At synapses, ions move across cell membranes through chemically-gated channels.
- The gates are opened or closed by neurotransmitters.

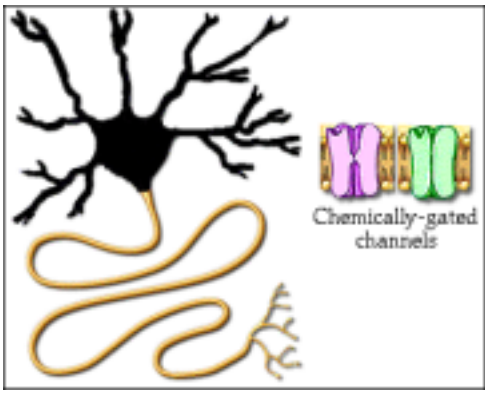
Page 2. Goals

- To review the types of ion channels.
- To learn how chemically-gated channels produce excitatory and inhibitory synaptic potentials.
- To understand that neurotransmitters may act directly, causing rapid postsynaptic potentials, or indirectly, causing slow postsynaptic potentials.

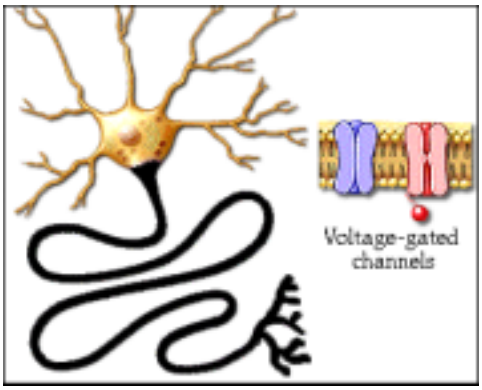
Page 3. Ion Channels Review



- Ion channels are regionally located in the neuron and are functionally unique.
- Passive channels are located in the cell membrane on the dendrites, the cell body, and the axon.
- Passive channels are responsible for establishing the resting membrane potential.
- This topic was studied in the module Nervous System: Action Potential.



- Most chemically-gated channels are located on the dendrites, and the cell body.
- Chemically-gated channels are responsible for producing synaptic potentials.
- Synaptic potentials will be studied in the last section of this module.

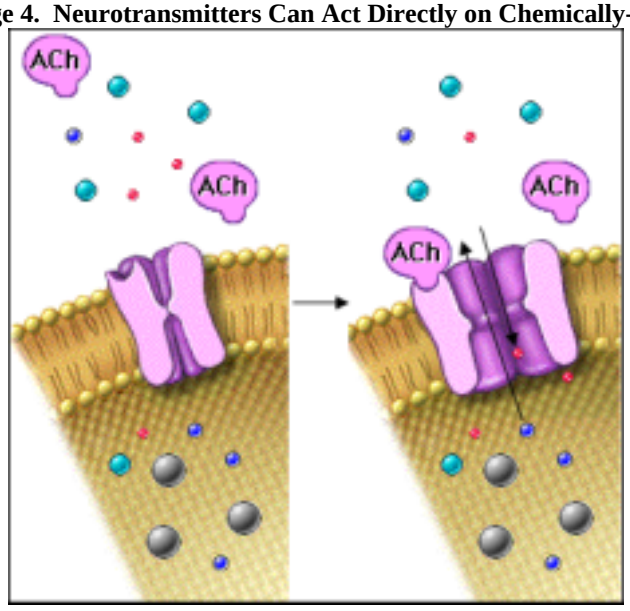


- Most voltage-gated channels are found on the axon hillock, all along unmyelinated axons, and at the nodes of Ranvier in myelinated axons.
- Voltage-gated channels are responsible for generation and propagation of the action potential.
- This topic was studied in the module Nervous System: Action Potential.

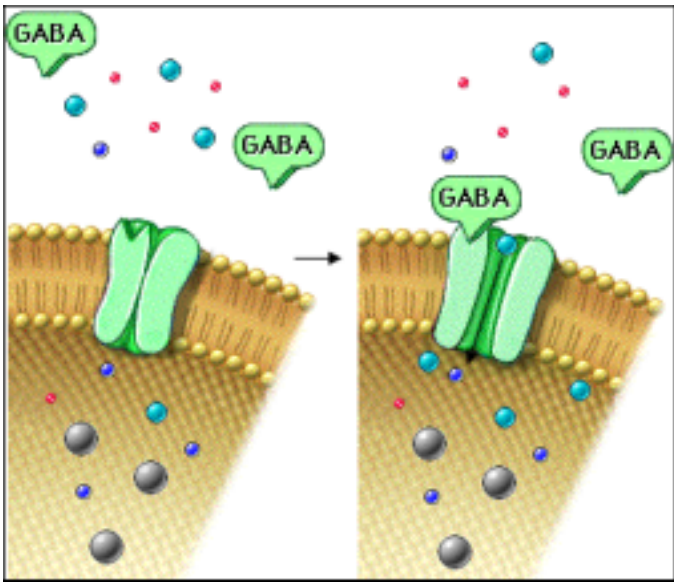
* Now is a good time to go to quiz questions 1:
  - Click the Quiz button on the left side of the screen.
  - Work through quiz questions 1.
  - When you are done remember to go to "Page 4. Neurotransmitters Can Act Directly on Chemically-gated

channels."

Page 4. Neurotransmitters Can Act Directly on Chemically-gated Channels

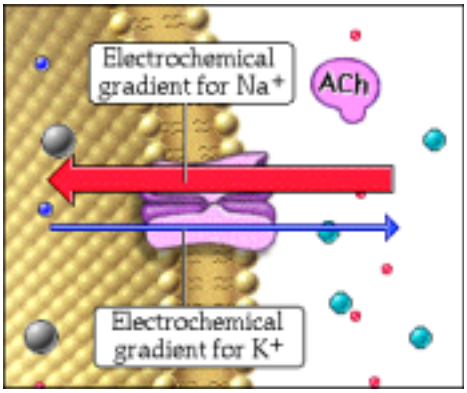


- Many receptors are physically part of an ion channel.
- Binding neurotransmitter to a receptor on the postsynaptic cell causes a change in the shape of the receptor.
- This can open, or in some cases close, the ion channel.
- Neurotransmitters that bind to ion channels are said to act directly.
- They cause a brief, rapid change in the membrane potential of the postsynaptic cell.
- Directly-acting neurotransmitters include acetylcholine, glutamate, GABA, and glycine.

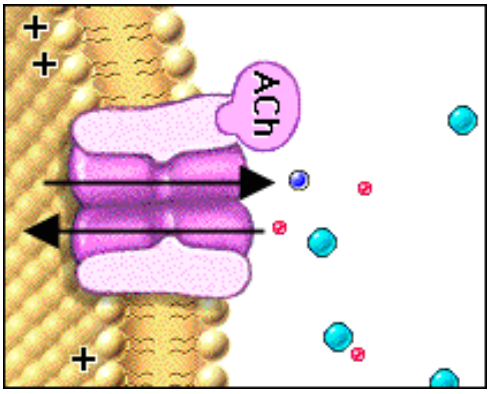


- We have shown only a single molecule of neurotransmitter binding to each channel.
- Ion channels typically have multiple binding sites for neurotransmitters and require the binding of more than one neurotransmitter molecule to open or close the channel.

Page 5. Ion Channels for Rapid EPSPs

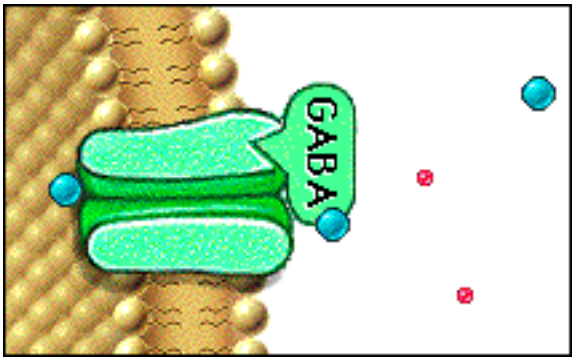


- An excitatory postsynaptic potential, or EPSP, is produced when the movement of ions makes the inside of the cell more positive.
- Ion channels at a typical excitatory synapse are specific for cations, having a watery pore large enough to pass both sodium and potassium.
- In a resting neuron, the electrochemical gradient for sodium is very large and causes sodium to move into the cell.
- The electrochemical gradient for potassium causes it to move out of the cell, but the gradient is very small.



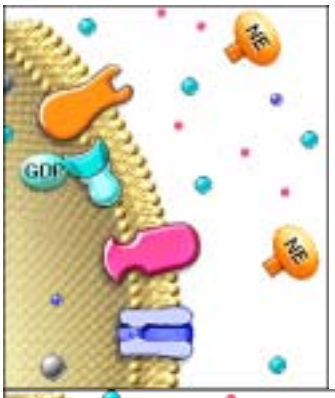
- Notice that more sodium moves into the cell than potassium moves out.
- Excitatory postsynaptic potentials depolarize neurons.
- If the neuron is depolarized to threshold, an action potential is generated.

Page 6. Ion Channels for Rapid IPSPs

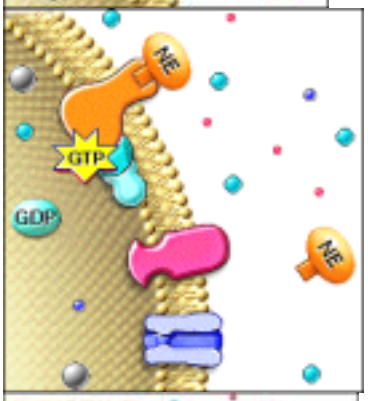


- An inhibitory postsynaptic potential, or IPSP, is produced when the movement of ions makes the inside of the cell more negative.
- Ion channels at a typical inhibitory synapse are specific for chloride and the electrochemical gradient for chloride causes it to move into the cell.
- Inhibitory postsynaptic potentials hyperpolarize neurons making the membrane potential more negative.
- Inhibitory postsynaptic potentials oppose excitability in the neuron and tend to prevent the neuron from generating an action potential.

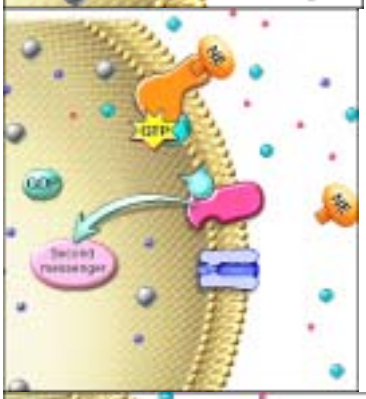
Page 7. Neurotransmitters Can Act Indirectly on Ion Channels



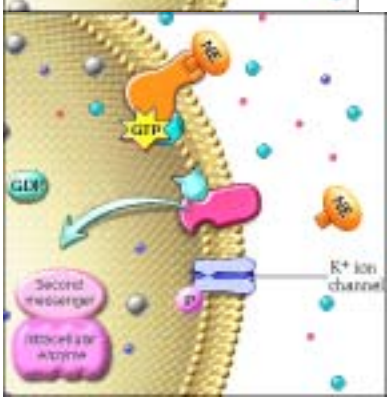
- Some neurotransmitters bind to receptors that are separate from ion channels.
- This process most often leads to production of intracellular second messengers, which ultimately alter ion channels.
- Such neurotransmitters are said to act indirectly.



- The receptor is coupled to the ion channel by a G protein.
- At rest, guanosine diphosphate, or GDP, is bound to the G protein.
- When norepinephrine binds to the receptor, the G protein is activated, releases GDP, and binds guanosine triphosphate, or GTP.
- GTP is a high-energy molecule.



- Part of the activated G protein travels in the membrane and activates an enzyme, which induces production of a second messenger.
- The neurotransmitter is the first messenger.



- The second messenger activates an intracellular enzyme, which phosphorylates a potassium ion channel and closes it.
- In the resting neuron, movement of potassium out of the cell acts to hyperpolarize the cell.
- Closing these channels results in the membrane potential becoming less negative and depolarizing the cell.

- Depolarization of the cell by the indirect method is time consuming.
- The resulting synaptic potential is slow in onset, and long in duration.
- Besides excitation, indirectly-acting neurotransmitters can also produce slow inhibition.
- The neurotransmitters acetylcholine, glutamate, GABA, and serotonin can act indirectly as well as directly, depending on the receptor to which they bind.
- The catecholamines (norepinephrine, epinephrine, and dopamine) and peptide neurotransmitters **ONLY** act indirectly.

Page 8. Summary

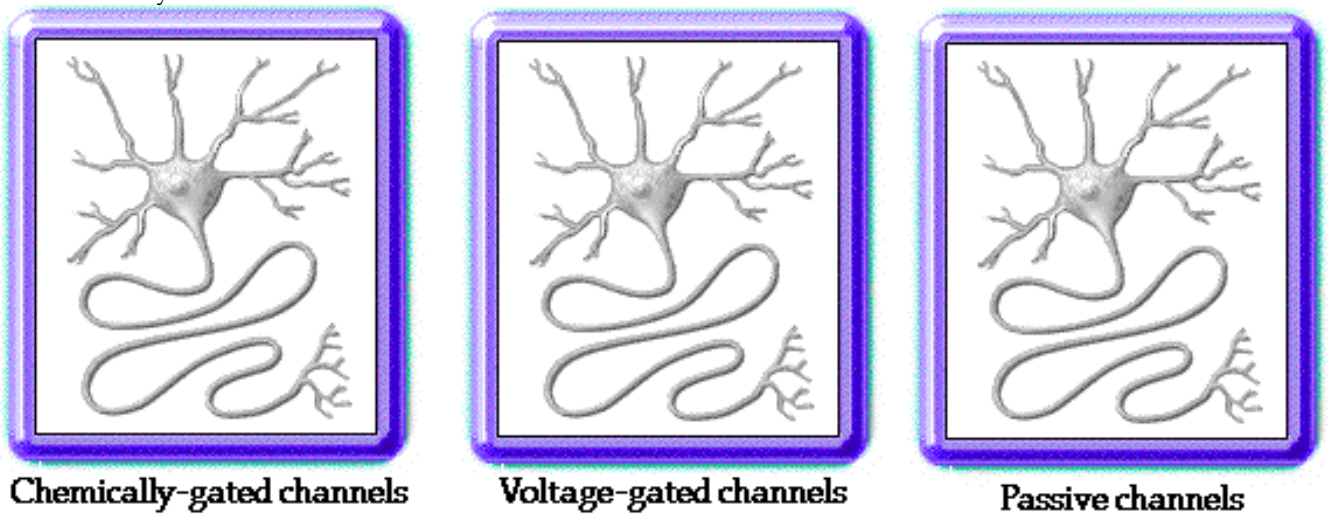
- Neurotransmitters that bind directly to chemically-gated channels produce rapid synaptic potentials, which may excite or inhibit the neuron.
- Ion channels responsible for rapid excitatory postsynaptic potentials permit both sodium and potassium to pass through them.
- Ion channels responsible for rapid inhibitory postsynaptic potentials typically permit chloride to pass through.
- Neurotransmitters that act indirectly produce slow postsynaptic potentials, which modulate the activity of neurons.

* Now is a good time to go to quiz questions 2-5:
  - Click the Quiz button on the left side of the screen.
  - Work through quiz questions 2-5.

Notes on Quiz Questions:

Quiz Question #1: Locate the Ion Channels

- This question asks you to determine where chemically-gated, voltage-gated, and passive channels are located.
- Record your answers here:



Continue to ION Channels - Part II
(Separate Document)