Ion Channels

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** There are a number of ion channels introducted in this topic which you will need to recognize in the next two topics. It is suggested that you carefully label each ion channel in the graphics in this section. If this is not printed in color, you should also color code the ion channels and ions as follows:

Red: Sodium ion channels and sodium ions
Blue: Potassium ion channels and potassium ions
Green: Chloride ion channels and chloride ions

Page 1. Introduction

- Ion channels control the movement of ions across the neuronal membrane.
- These tiny anatomical structures make neurons excitable.

Page 2. Goals

- To understand what ion channels are.
- To learn where ion channels are located.
- To understand how ion channels function.

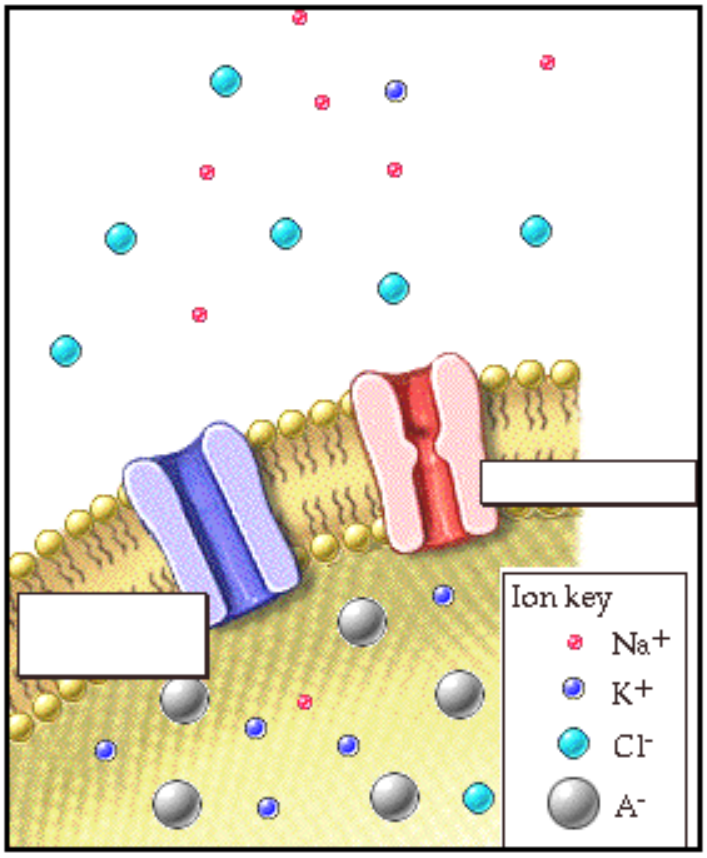
Page 3. Neuronal Cell Membranes Contain Ion Channels

- Recall that the cell membrane is a lipid bilayer in which large protein molecules, called integral proteins, are embedded. Some of the integral proteins contain watery pores called ion channels, through which charged particles, or ions, can pass.
- Ion channels control the movement of ions through the neuronal cell membrane.

- The channels are:
  1. selective
  2. either passive or active
  3. regionally located
  4. functionally unique

Page 4. Ion Channels Are Selective

- Ion channels are selective. They allow some ions to pass through and prevent the passage of others.
- Channel selectivity depends on:
  1. the charge on the ion—that is, whether it is positive or negative
  2. on the size of the ion
  3. on how much water the ion attracts and holds around it
- On this diagram:
  - Label and color code the ions and ion channels.

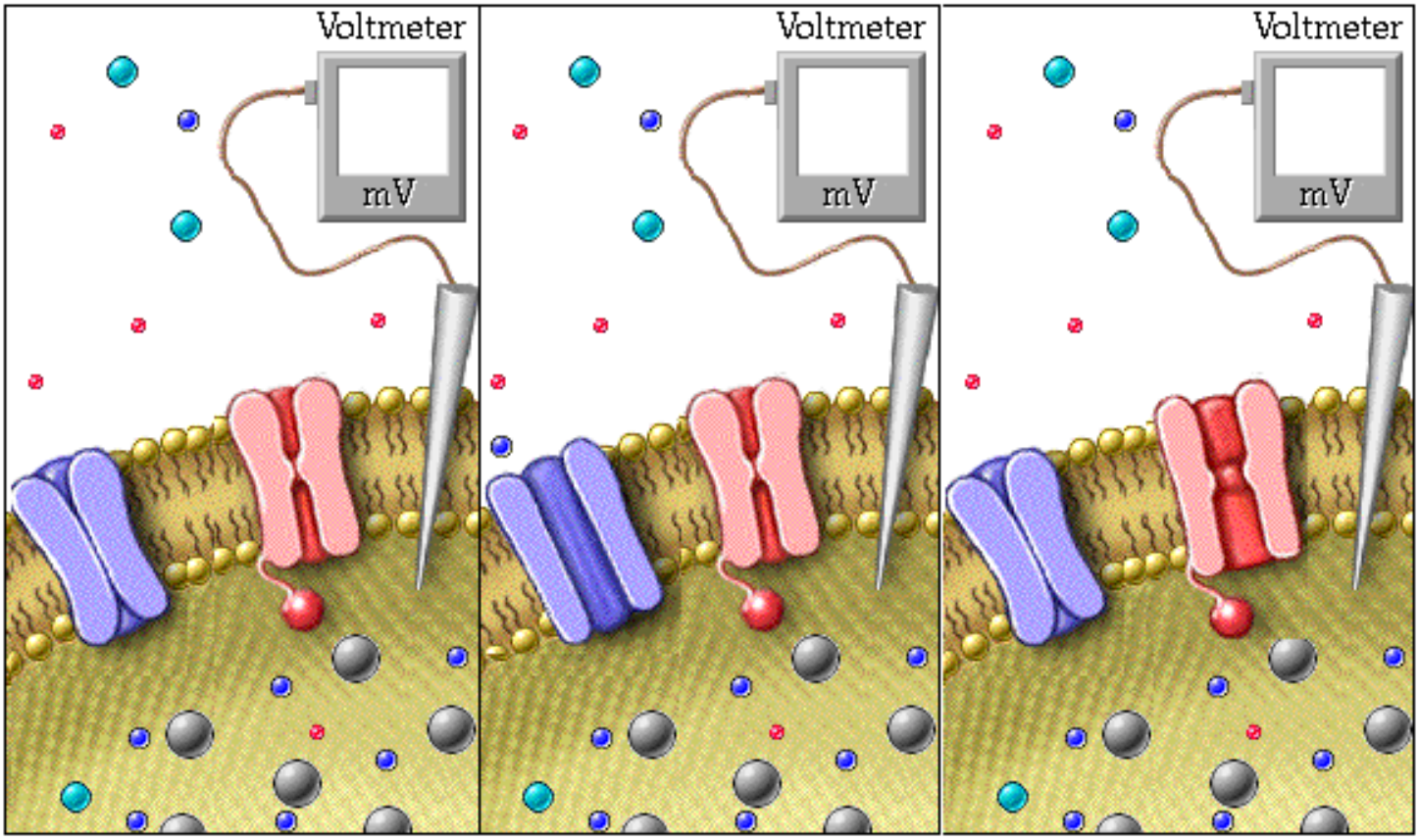


Page 5 Passive Ion Channels Are Always Open

- Ion channels are either active or passive:
  - **Active Channels.** Active channels have gates that can open or close the channel.
  - **Passive Channels.** Passive channels, also called leakage channels, are always open and ions pass through them continuously.

Page 6. Some Active Channels Have Voltage-Controlled Gates

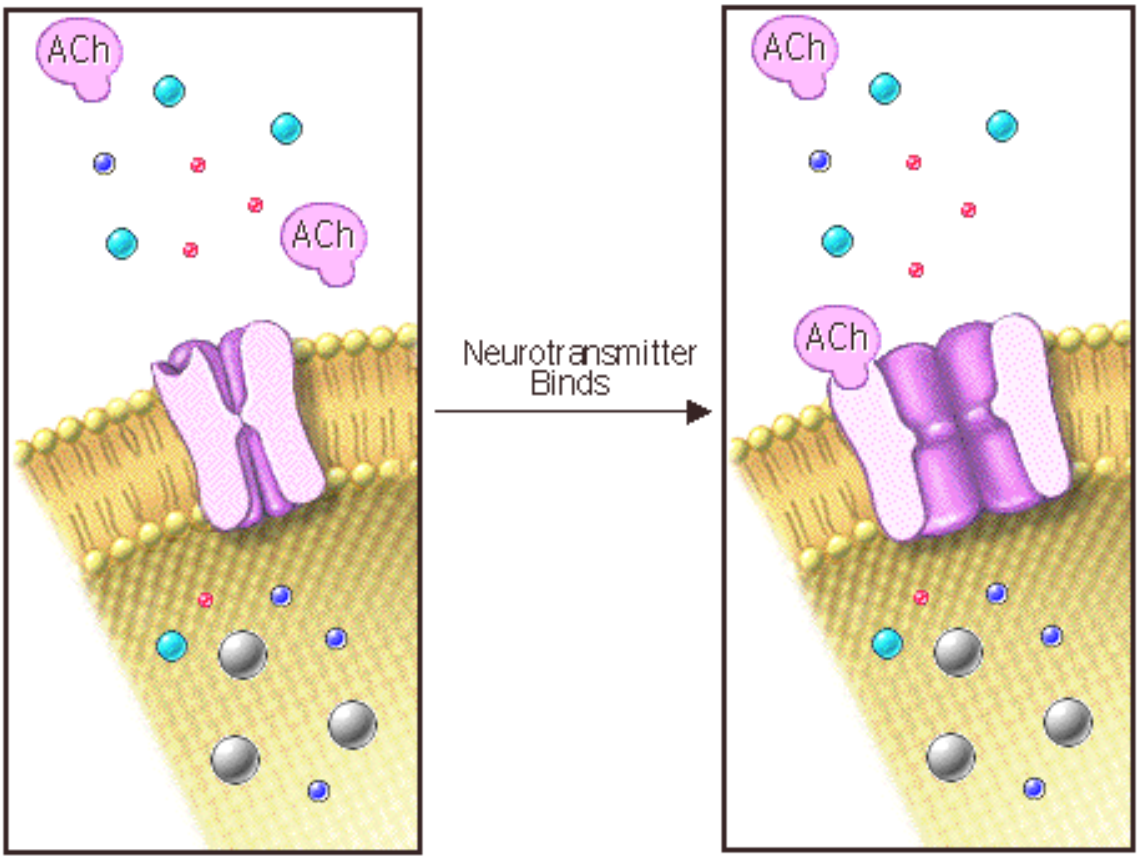
- Active channels have gates that can open and close the channel.
- Some active channels, called voltage-gated channels, have gates that are controlled by voltage.
- Recall that cells have slightly more positive ions on the outside of their membranes, and slightly more negative ions on the inside.
  - This difference produces a voltage, called the membrane potential, across the cell membrane.
  - We can measure the membrane potential and display it on a voltmeter.
- When a neuron is at rest, voltage-gated channels are closed.
- During an action potential, the voltage across the membrane changes, causing voltage-gated channels to open and close.
- Ions move through the open channels.
- When the Na^+ voltage-gated channel opens, membrane potential goes from -70 mV to less negative values. This is because a positive ion is moving inward, making the inside of the membrane more positive.
- When the K^+ voltage-gated channel opens, membrane potential goes from +30 mV to more negative values -70. This is because a positive ion is moving outward, making the inside of the membrane more negative.
- Label and color code the ions and ion ion channels. In each of these situations, indicate the value(s) of the membrane potential:



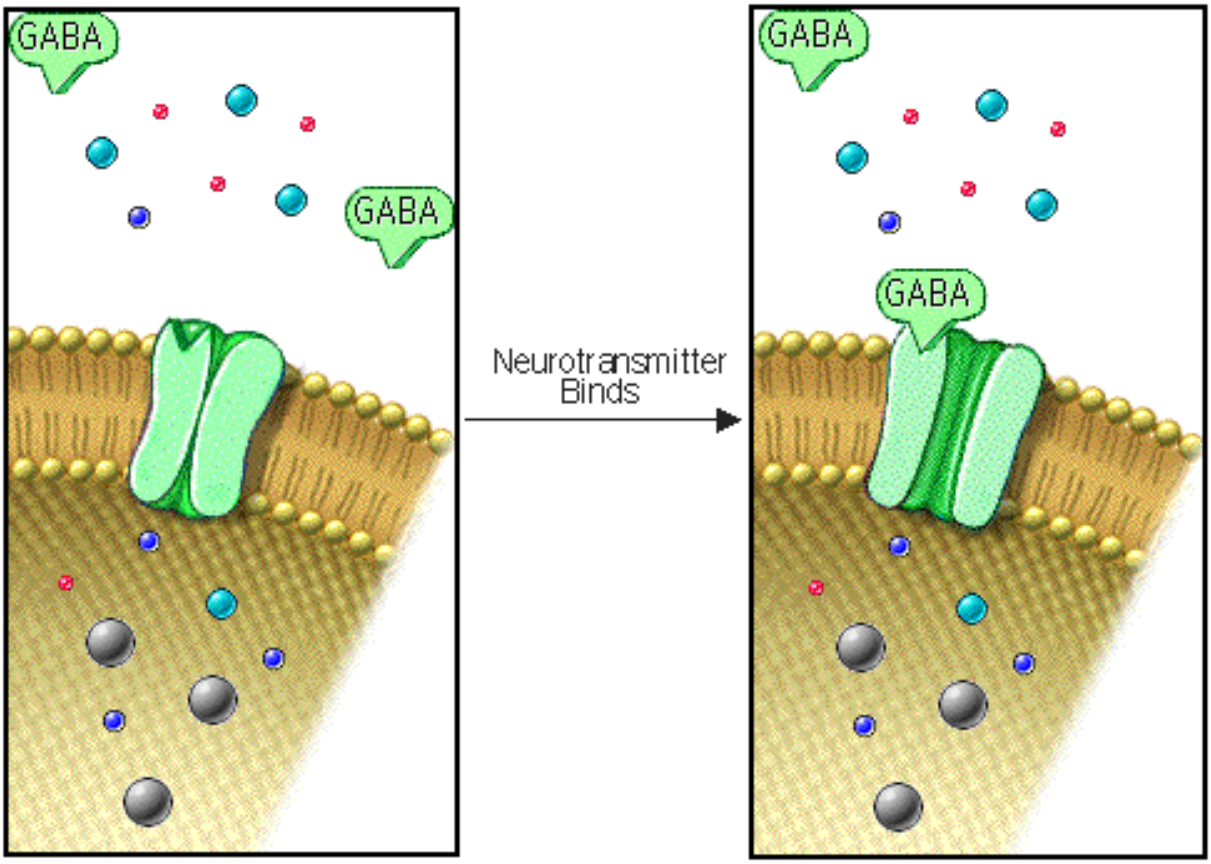
Page 7. Some Active Channels Have Chemically-Controlled Gates

- Types of Gated Channels:
  1. Voltage-gated Channels
  2. Chemically-gated Channels
- **Chemically-gated Channels.** Now let's look at channels that have gates controlled by chemicals, in particular by neurotransmitters such as acetylcholine and GABA. When these neurotransmitters bind to chemically-gated channels, they cause the channels to open, thereby permitting ions to move across the membrane.
- On the diagrams on the next page, which show the action of acetyl choline and GABA, color the acetyl choline and the acetyl choline receptor purple. Color the GABA and the GABA receptors green. Color the sodium ions red, the potassium ions blue and the chloride ions green.
- When acetyl choline binds to it's receptor, which ion(s) will move across the membrane?

  _____



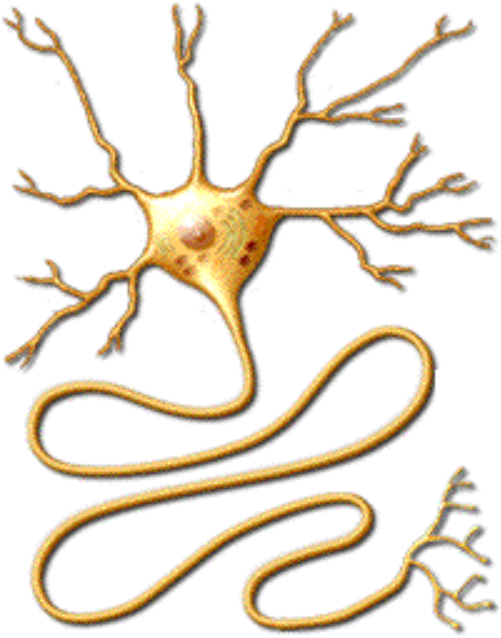
• When GABA binds to it's receptor, which ion(s) will move across the membrane? _____



Page 8. Ion Channels Are Regionally Located

• Ion channels—passive, chemically-gated, or voltage gated—are regionally located in the neuron.

• As you work through this page, draw lines to connect the channel types to the areas they are found on the neuron. Also label and color code the ions and ion ion channels:



Passive channels

Chemically-gated channels

Voltage-gated channels

• Passive channels are located in the cell membrane all over the neuron—on dendrites, the cell body, and the axon.
• For the most part, chemically-gated channels are located on the dendrites and cell body of the neuron.
• For the most part, voltage-gated channels are found on the axon hillock, all along unmyelinated axons, and at the nodes of Ranvier in myelinated axons.

Page 9. Ion Channels Are Functionally Unique

• Ion channels have specific functions, which are suggested by their locations on the neuron:
  • **Passive Channels.** Passive channels are responsible for the resting membrane potential.
  • **Chemically-gated Channels.** Chemically-gated channels are responsible for synaptic potentials, the incoming signals to the neuron.
  • **Voltage-gated Channels.** Voltage-gated channels are responsible for generation and propagation of the action potential, the outgoing signal from the neuron.

Page 10. Summary

• Integral membrane proteins containing watery pores form channels through which ions move.
• Some ion channels, called passive or leakage channels, are always open.
• Some ion channels have gates that open and close, permitting ions to pass through them only under certain conditions.
• Regionally located ion channels are responsible for the resting membrane potential, synaptic potentials, and the generation and propagation of the action potential.

** Now is a good time to go to quiz questions 1-6.
  • Click the Quiz button on the left side of the screen.
  • Work through quiz questions 1-6.

Notes on Quiz Questions:

Quiz Question #1: Features of Ion Channels

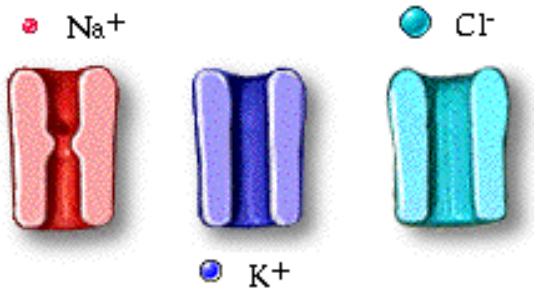
• This question asks you to characterize the differences between passive and active ion channels.

Quiz Question #2: Ion Channel Selectivity

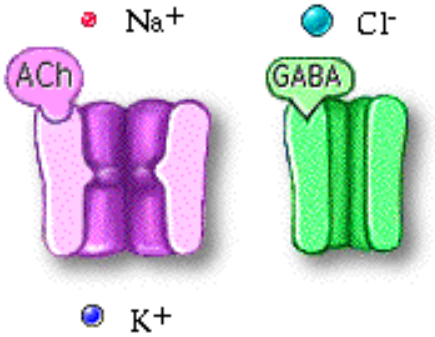
• This question asks you to identify the specific ions that pass through each type of ion channel.
• You may want to label and colorcode the ion channels and take notes on the diagram below:

Summary of Ion Channels:

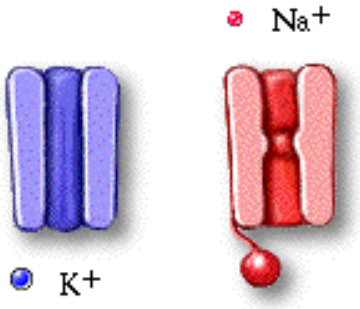
Passive Ion Channels
- Found on dendrites, cell body, and axon.



Chemically-gated Ion Channels
- Found on dendrites & cell body.



Voltage-gated Ion Channels
- Found on axon hillock, unmyelinated axons and at nodes of Ranvier on myelinated axons.



Quiz Question #3: The Gatekeeper 1
- This question asks you to identify a type of ion channel from the clues given.

Quiz Question #4: The Gatekeeper 2
- This question asks you to identify a type of ion channel from the clues given.

Quiz Question #5: Ion Channel Location
- This question asks you to identify the location of the various ion channels on a neuron.

Quiz Question #6: The Puffer Fish
- This question asks you to predict the effects of tetrodotoxin poisoning.
- Tetrodotoxin is present in the gonads of Puffer fish. It blocks voltage-gated sodium channels so that action potentials can't occur. Since nerve impulse can't occur, impulses to muscle can't occur, including the muscle that controls breathing.

Study Questions on Ion Channels:

1. (Page 3.) What controls the movement of ions across the membrane of a neuron?
2. (Page 3.) What are four properties of ion channels?
3. (Page 3.) What are ion channels made of?
4. (Page 4.) What does it mean to say "Ion channels are selective"?
5. (Page 4.) What three factors determine the selectivity of an ion channel?
6. (Page 5.) What's the difference between an active and passive ion channel?
7. (Page 6.) Is a resting neuronal cell membrane more positive inside or outside?
8. (Page 6.) What is the result of the charge separation in a resting neuronal membrane?
9. (Page 6.) When the neuronal membrane is at rest are the voltage-gated channels opened or closed?

10. (Page 6.) What happens to the voltage-gated channels when there is a nerve impulse (or action potential) in the neuronal membrane?

11. (Page 6.) Why, when the Na^+ voltage-gated channel opens, does the membrane potential goes from -70 mV to less negative values.

12. (Page 6.) Why, when the K^+ voltage-gated channel opens, does the membrane potential goes from +30 mV to more negative values (-70).

13. (Page 7.) Give two general types of active channels.

14. (Page 7.) What will open a chemically-gated ion channel in a neuron?

15. (Page 7.) When a neurotransmitter opens a chemically-gated channel, does the neurotransmitter go into the cell?

16. (Page 7.) When acetyl choline binds to its receptor, which ion(s) will move across the membrane? In which direction will they move?

17. (Page 7.) When acetyl choline binds to its receptor, which ion(s) will move across the membrane? In which direction will they move?

18. (Page 7.) What determines the direction that ions move through an ion channel?

19. (Page 8.) On what parts of the neuron do we find passive channels?

20. (Page 8.) On what parts of the neuron do we find chemically-gated channels?

21. (Page 8.) On what parts of the neuron do we find voltage-gated channels?

22. (Page 9.) Match the channel type to its function:
    A. Passive Channels
    B. Chemically-gated channels
    C. Voltage-gated channels
        x. are responsible for the generation of the action potential (nerve impulses)- the outgoing signal from the neuron
        y. are responsible for potentials generated at synapses (synaptic potentials)
        z. are responsible for the resting membrane potential

Answers to Study Questions on Ion Channels:

1. Ion channels.
2. Selective, Passive or Active, Regionally Located, Functionally Unique
3. Integral membrane proteins embedded in the cell membrane.
4. Ion channels allow some ions to pass through and prevent the passage of other ions.
5. (1) the charge of the ion (positive or negative) (2) the size of the ion (3) how much water the ion holds and attracts
6. Active channels have gates that can open or close the channel. Passive channels are always open and ions pass through them continuously.
7. There are slightly more positive ions on the outside and slightly more negative ions on the inside.
8. There is a voltage produced called the membrane potential across the cell membrane.
9. When a neuron is at rest, the voltage gated channels are closed.
10. During an action potential, the voltage across the membrane changes, causing voltage-gated channels to open and close. Ions will then move through the open channels.
11. Because a positive ion is moving inward, making the inside of the membrane more positive.
12. Because a positive ion is moving outward, making the inside of the membrane more negative.
13. Voltage-gated channels and Chemically-gated channels
14. A neurotransmitter.
15. No, the neurotransmitter does not go into the cell. It binds to the channel and causes the channel to open, then ions go in and out of the cell.
16. Sodium ion moves from the outside of the cell to the inside of the cell and potassium ion moves from the inside of the cell to the outside of the cell.
17. Chloride ion moves from the outside of the cell to the inside of the cell.
18. Ions move passively from higher concentration to lower concentration down the concentration gradient.
19. All over the neuron including dendrites, cell body, and axon.
20. Only on dendrites & cell body (not on the axons).
21. On axons.

22. A. z B. y C. x