ELECTRICAL AND CHEMICAL COMMUNICATION IN THE NERVOUS SYSTEM WORKSHEET

ABOUT THIS WORKSHEET

This worksheet complements the "Electrical Activity of Neurons" Click and Learn activity that examines neuronal communication in the nervous system. While completing this worksheet, you will explore how electrical signals are generated within neuronal cells and consider how these electrical signals are converted into chemical signals at junctures between different neuronal cells called synapses.

PROCEDURE

Start the Click and Learn at https://www.hhmi.org/biointeractive/electrical-activity-neurons/. As you read through the slides and watch the animations and videos, answer the following questions. Be sure to read each slide, even if there aren't questions from that slide.

QUESTIONS

Slide 1 animation:

1. How many neurons are shown in the circuit in this animation? (select one)

A) One neuron.
B) Two neurons.
C) Three neurons.
D) Four neurons.
E) Unable to answer.

2. What are represented by the white "flashes" that move along the neurons?

3. Information moves from one neuron to another across a structure called the ______________.

4. Two types of synapses exist:
(i) Electrical synapses pass electrical signals directly between the cytoplasm of two cells.
(ii) Chemical synapses pass chemical signals called neurotransmitters from one cell to another across an extracellular space called the synaptic cleft.

What kind of synapses are shown in this animation? (select one)

A) Only electrical synapses.
B) Only chemical synapses.
C) Both electrical and chemical synapses.

5. Information transfer at the type of synapse shown in this animation occurs (select one):

A) in a single direction from dendrite to synaptic terminal.
B) back-and-forth between dendrite and synaptic terminal.
C) in a single direction from synaptic terminal to dendrite.

6. What triggers calcium entry into the synaptic terminal?

7. Describe the role of calcium in information transfer from one neuron to another across the synapse in this animation.

8. Chemicals called chelators can be introduced to the body experimentally to bind specific ions and remove these ions from solution. For example, BAPTA is a calcium-specific chelator that binds to and prevents normal calcium functioning. Predict the outcomes upon neurotransmission in the synapses of this animation immediately following the injection of BAPTA into the structures/regions below and *justify your answers*.

a. **Synaptic terminal.**

b. **Dendrite**.

c. **Extracellular fluid**.

9. According to the animation, what happens to neurotransmitters that are released from the synaptic terminal?

Slide 2:

10. **Model organisms** are species that have been widely studied and are used in neuroscience research because they can be kept in a laboratory setting, have specific experimental advantages, and the knowledge gained from studies of these organisms provides insight into the biological processes of other species. Thus, studies of model organisms with simpler nervous systems can provide insight into the function of more complex nervous systems with a greater number of neurons and synapses.

In this click-and-learn, *Aplysia,* a marine mollusk commonly referred to as a "sea slug," is used as a model organism to study neuronal activity. Based on the information above, and from **slide 2**, which of the following statements about studies of the electrical activity of *Aplysia* neurons is/are **correct**? Choose all that apply.

A) Scientists who study *Aplysia* are solely interested in learning about the neurobiology of mollusks.
B) *Aplysia* cannot survive in a laboratory setting.
C) *Aplysia* have large neurons that allow for ease of inserting a recording electrode.
D) Knowledge gained from studies of *Aplysia* is only applicable to mollusk neurobiology.
E) Knowledge gained from studies of *Aplysia* is only applicable to nervous systems with a similar number of neurons and synapses.
F) Knowledge gained from studies of *Aplysia* can provide insight into the electrical activity of neurons from more complex species.
G) The cost of maintaining *Aplysia* in a laboratory setting is prohibitive.
H) Recording from neurons of mammalian species, such as the mouse, is easier than recording from *Aplysia* neurons.

11. Neuroscientists typically show electrical activity as a graph of ______________ on the X-axis and ______________ on the Y-axis.

Slide 3:

12. What types of neurons are visible on the culture dish?

13. Under the pictured conditions, can the sensory neuron be stimulated to fire an action potential?

14. Under the pictured conditions, is there evidence that action potentials can be recorded in the motor neuron?

Slides 4 and 5:

15. Based on the information on slides 4 and 5, which of the following statements about the generation of an action potential is **false**? (select one)

A) Under natural conditions, stimuli such as touch can trigger action potentials.
B) Electrical stimulation of a neuron can trigger action potentials.
C) Stimulation below the threshold value does not change the voltage of a neuron.
D) Stimulation below the threshold value does not stimulate a neuronal action potential.
E) Stimulation above the threshold value stimulates a neuronal action potential.

16. Sub-threshold changes in membrane potential can be either:

i) Excitatory – changing the neuronal membrane potential closer to the threshold value.
ii) Inhibitory – changing the neuronal membrane potential further away from the threshold value.

a) How many sub-threshold stimuli are shown in the video of this recording?

A) 1
B) 2
C) 3
D) 4
E) Too many to count.

b) Are these sub-threshold stimuli excitatory or inhibitory?

Slide 6:

17. Under the pictured conditions, can the sensory neuron be stimulated to fire an action potential? Justify your answer.

18. Under the pictured conditions, can action potentials be recorded in the motor neuron? Why or why not?

Slide 8:

19. Under the conditions in this video, is neurotransmitter released from the sensory neuron? Why or why not?

Slide 9:

20. Under the conditions in this video, is neurotransmitter released from the sensory neuron? Why or why not?

21. Was an action potential generated in the motor neuron? Why or why not?

22. Under the conditions in this video, what can you do to stimulate the firing of an action potential in the motor neuron?

<u>Extension questions:</u>

Under living conditions, excitatory and inhibitory sub-threshold changes in membrane potential are called **graded potentials** or **synaptic potentials.** Graded potentials are generated by opening either ligand-gated or mechanically-gated ion channels in the plasma membrane of the dendrites and/or cell body of a neuron.

When the threshold voltage of a neuronal plasma membrane is reached by the addition, or summation, of graded potentials, voltage-gated ion channels are stimulated to open and generate an action potential.

23. Complete the table below comparing the three types of gated ion channels. You may need to look up some of the answers.

Gated ion-channel type	**Location of gated ion-channel in a neuron**	**Stimulated (opened) by**	**Membrane potential change generated when open** (graded or action potential)
Ligand-gated			
Mechanically-gated			
Voltage-gated			

24. Which of the following statements regarding the voltage recordings in the video of **slide #5** is/are **correct**? Choose <u>all</u> that apply. In this video:

A) sub-threshold graded potentials are generated by opening mechanically-gated ion channels.
B) voltage-gated ion channels are stimulated to open by injection of any electrical current resulting in an action potential.
C) sub-threshold graded potentials are generated by adding neurotransmitter to the dendrites and cell bodies of the sensory neuron.
D) the electrical current injected into the sensory neuron at the end of the video was strong enough to raise the membrane voltage above a threshold value.
E) The electrical current injected into the sensory neuron at the end of the video was strong enough to open ligand-gated ion channels.
F) The electrical current injected into the sensory neuron at the end of the video was strong enough to open voltage-gated ion channels.

25. Consider the video of ***slide #8***.

a) What kind of gated ion channels open in the motor neuron when the sensory neuron is stimulated? (select one)

A) Only ligand-gated ion channels opened in the motor neuron.
B) Only mechanically-gated ion channels opened in the motor neuron.
C) Only voltage-gated ion channels opened in the motor neuron.
D) No gated ion channels opened in the motor neuron.
E) All of these gated ion channels opened in the motor neuron.

b) Explain your answer to part "a" above.

26. Consider the video of ***slide #9***.

a) What kind of gated ion channels open in the motor neuron following the sensory neuron action potential? (select one)

A) Only ligand-gated ion channels opened in the motor neuron.
B) Only mechanically-gated ion channels opened in the motor neuron.
C) Only voltage-gated ion channels opened in the motor neuron.
D) No gated ion channels opened in the motor neuron.
E) All of these gated ion channels opened in the motor neuron.

b) Explain your answer to part "a" above.

27. Based on the information in ***slide #10***, is the following statement true or false? If false, correct the statement.

"Single graded (or synaptic) potentials are sufficient to generate action potentials in a neuron."