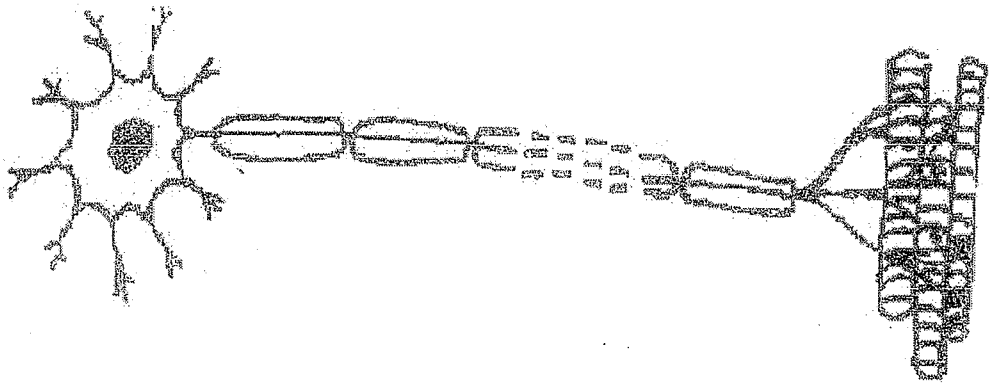
The Nervous System Worksheet

Name: _____ Period: _____ Date: _____

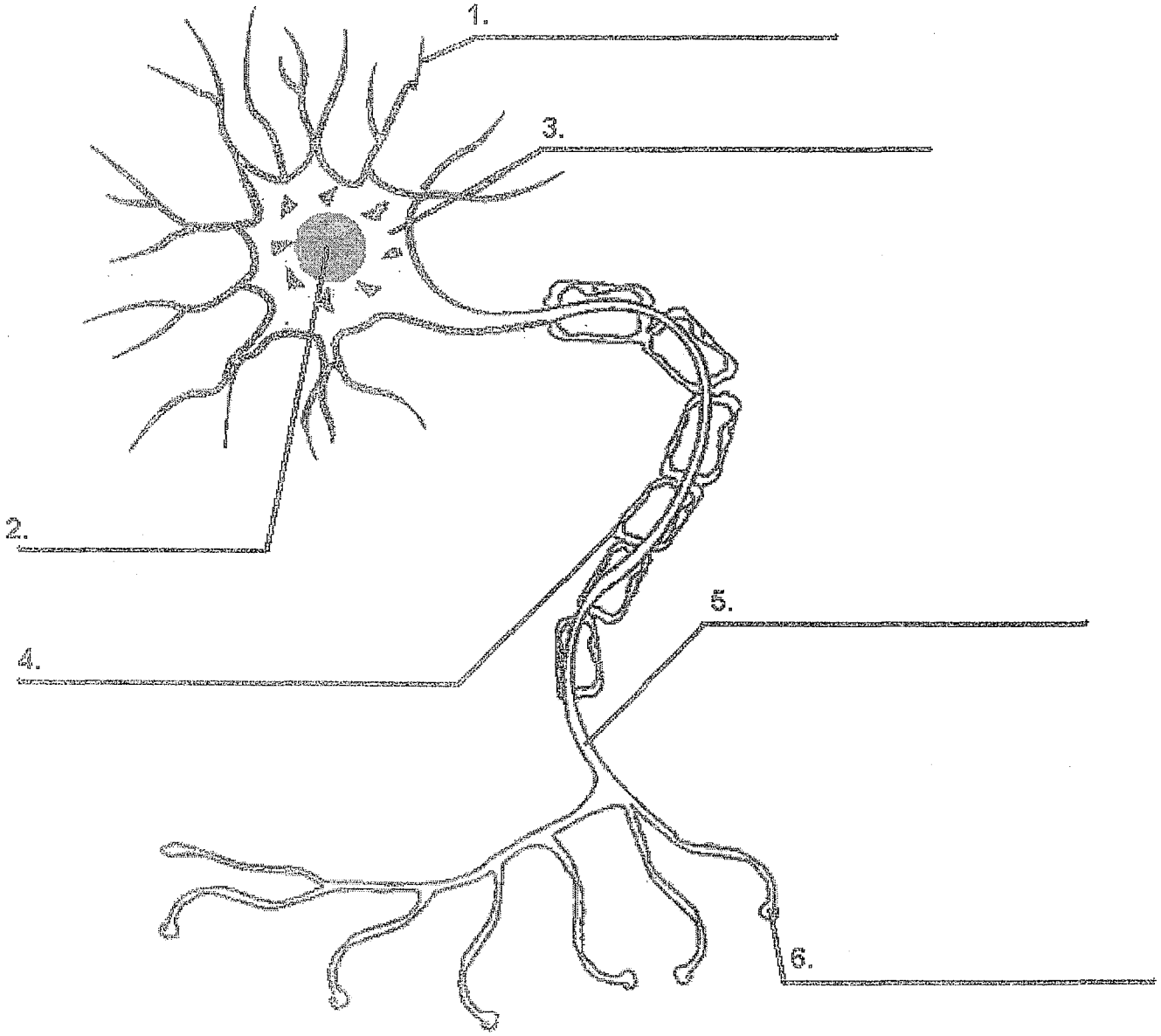
1. The diagram below is of a nerve cell or neuron.
   i. Add the following labels to the diagram.
   Axon; Myelin sheath; Cell body; Dendrites; effector cell; synapse
   ii. If you like, color in the diagram as suggested below.
      Axon - purple;
      Myelin sheath - yellow;
      Cell body - blue;
      Dendrites - green;
      Muscle fibers – red;
   iii. Use an arrow to indicate the direction that the nerve impulse travels.



2. There are three different kinds of neurons or nerve cell. Match each kind with its function.

Motor neuron; Sensory neuron; Relay neuron;

Kind of neuron	Function
	The nerve cell that carries impulses from a sense receptor to the brain or spinal cord.
	The nerve cell that connects sensory and motor neurons
	The nerve cell that transmits impulses from the brain or spinal cord to a muscle or gland


1.
3.
2.
5.
4.
6.

Name:_____ Date:_____

Action Potential

During an action potential, ions cross back and forth across the neuron's membrane, causing electrical changes that transmit the nerve impulse:

1. The stimulus causes sodium channels in the neuron's membrane to open, allowing the Na^+ ions that were outside the membrane to rush into the cell.

The sodium channels are called *gated ion channels* because they can open and close in response to signals like electrical changes. When the Na^+ ions enter the neuron, the cell's electrical potential becomes more positive.

2. If the signal is strong enough and the voltage reaches a *threshold,* it triggers the action potential.

More gated ion channels open, allowing more Na^+ ions inside the cell, and the cell *depolarizes* so that the charges across the membrane completely reverse: The inside of the cell becomes positively charged and the outside becomes negatively charged.

3. The peak voltage of the action potential causes the gated sodium channels to close and potassium channels to open.

Potassium ions move outside the membrane, and sodium ions stay inside the membrane, *repolarizing* the cell. The result is a polarization that's opposite of the initial polarization that had Na^+ ions on the outside and K^+ions on the inside.

4. The neuron becomes *hyperpolarized* when more potassium ions are on the outside than sodium ions are on the inside.

When the K^+ gates finally close, the neuron has slightly more K^+ ions on the outside than it has Na^+ ions on the inside. This causes the cell's potential to drop slightly lower than the resting potential.

5. The neuron enters a *refractory period,* which returns potassium to the inside of the cell and sodium to the outside of the cell.

The sodium-potassium pump goes back to work, moving Na^+ ions to the outside of the cell and K^+ ions to the inside, returning the neuron to its normal polarized state.

For **questions 1–4**, use the following terms to fill in the blanks in each statement.

a. Inside

b. Outside

c. Positively charged

d. Negatively charged

1. The sodium-potassium pump moves sodium to the _____ of the cell.
2. The sodium-potassium pump moves potassium to the _____ of the cell.
3. During a resting potential, the cell's cytoplasm is _____ relative to the outside of the cell.
4. At the peak of the action potential, the cell's cytoplasm is _____ relative to the outside of the cell.

For **questions 5–10**, use the terms that follow to label the action potential shown in the following figure.

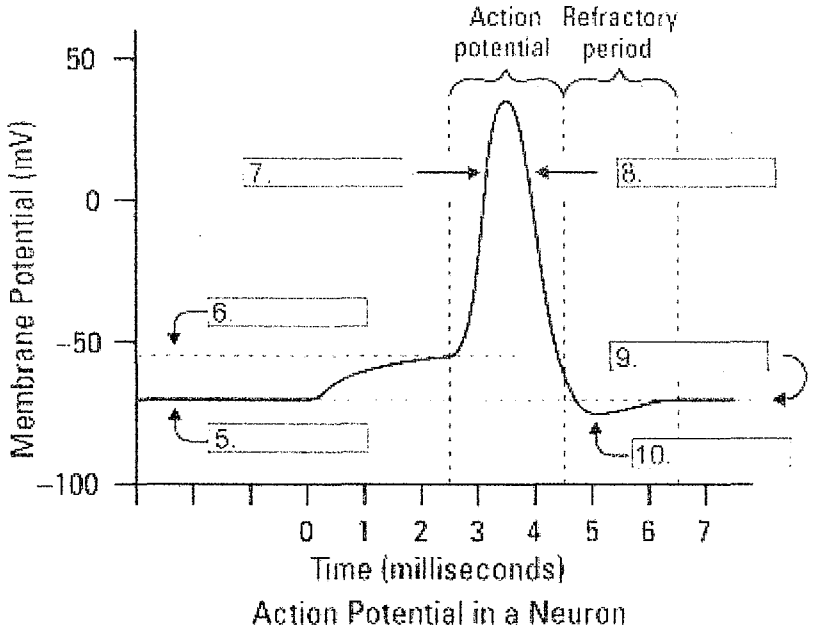
a. Threshold

b. Resting potential

c. Depolarization

d. Repolarization

e. Hyperpolarization



Action Potential in a Neuron

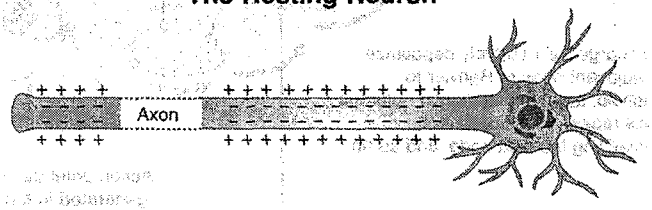
The transmission of a nerve impulse.

93 The Nerve Impulse

Key idea: A nerve impulse involves the movement of an action potential along a neuron as a series of electrical depolarization events in response to a stimulus.

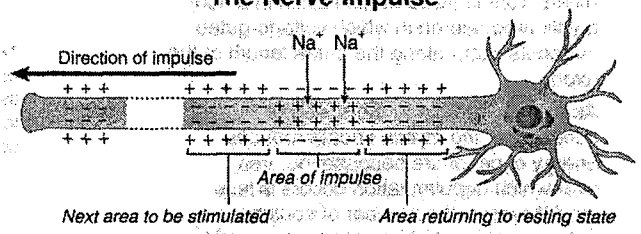
The plasma membranes of cells, including neurons, contain **sodium-potassium ion pumps** which actively pump sodium ions (Na^+) out of the cell and potassium ions (K^+) into the cell. The action of these ion pumps in neurons creates a separation of charge (a potential difference or voltage) either side of the membrane and makes the cells **electrically excitable**. It is this property that enables neurons to transmit electrical impulses. The **resting state** of a neuron, with a net negative charge inside, is maintained by the sodium-potassium pumps, which actively move two K^+ into the neuron for every three Na^+ moved out (below left). When a nerve is stimulated, a brief increase in membrane permeability to Na^+ temporarily reverses the membrane polarity (a **depolarization**). After the nerve impulse passes, the sodium-potassium pump restores the resting potential.

The Resting Neuron

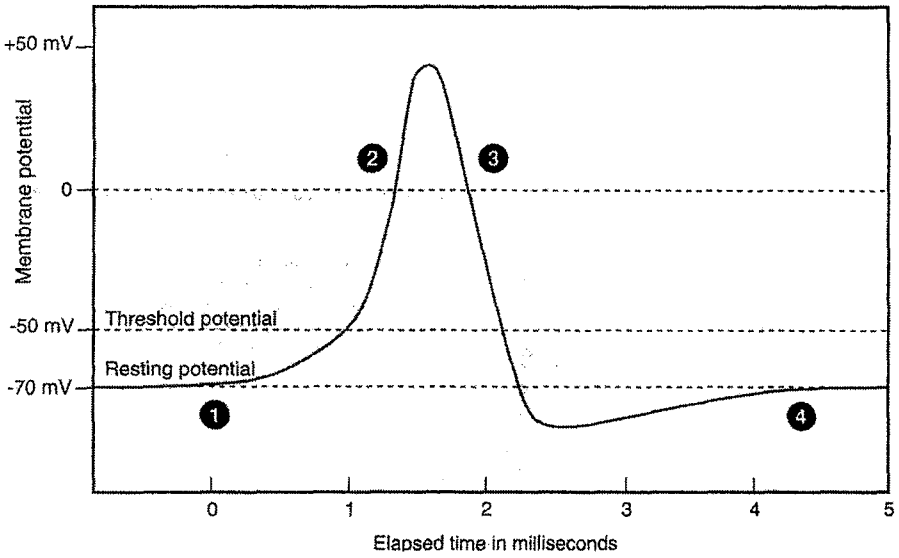


When a neuron is not transmitting an impulse, the inside of the cell is negatively charged relative to the outside and the cell is said to be electrically polarized. The potential difference (voltage) across the membrane is called the **resting potential**. For most nerve cells this is about -70 mV. Nerve transmission is possible because this membrane potential exists.

The Nerve Impulse



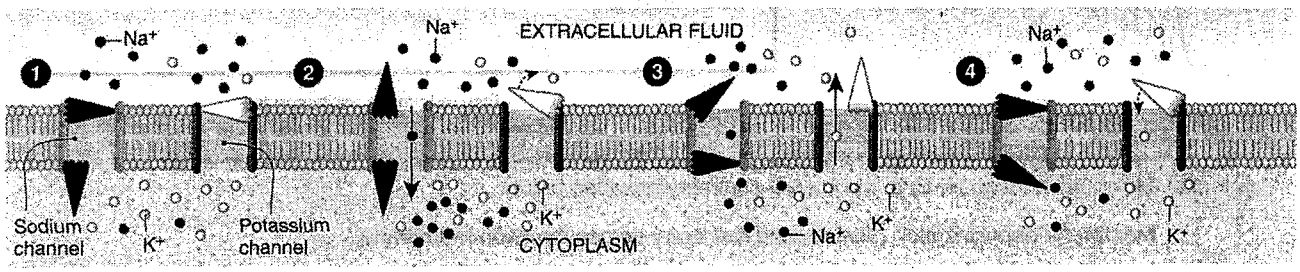
When a neuron is stimulated, the distribution of charges on each side of the membrane briefly reverses. This process of **depolarization** causes a burst of electrical activity to pass along the axon of the neuron as an **action potential**. As the charge reversal reaches one region, local currents depolarize the next region and the impulse spreads along the axon.



The depolarization in an axon can be shown as a change in membrane potential (in millivolts). A stimulus must be strong enough to reach the **threshold potential** before an action potential is generated. This is the voltage at which the depolarization of the membrane becomes unstoppable.

The action potential is **all or nothing** in its generation and because of this, impulses (once generated) always reach threshold and move along the axon without attenuation. The resting potential is restored by the movement of potassium ions (K^+) out of the cell. During this **refractory period**, the nerve cannot respond, so nerve impulses are discrete.

Voltage-Gated Ion Channels and the Course of an Action Potential



Resting state:
Voltage activated Na^+ and K^+ channels are closed.

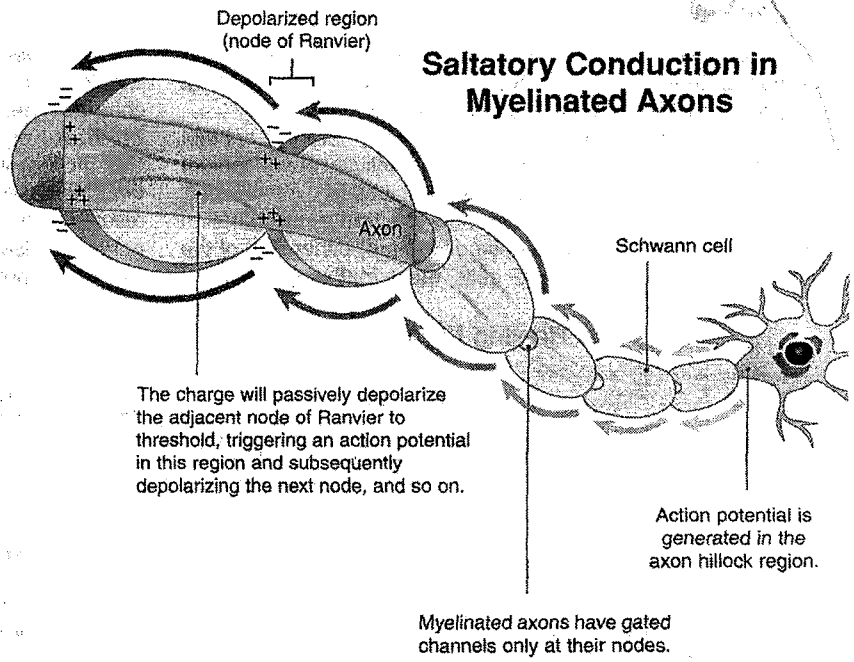
Depolarization:
Voltage activated Na^+ channels open and there is a rapid influx of Na^+ ions. The interior of the neuron becomes positive relative to the outside.

Repolarization:
Voltage activated Na^+ channels close and the K^+ channels open; K^+ moves out of the cell, restoring the negative charge to the cell interior.

Returning to resting state:
Voltage activated Na^+ and K^+ channels close to return the neuron to the resting state.

Axon myelination is a feature of vertebrate nervous systems and it enables them to achieve very rapid speeds of nerve conduction. Myelinated neurons conduct impulses by **saltatory conduction**, a term that describes how the impulse jumps along the fibre. In a myelinated neuron, action potentials are generated only at the nodes, which is where the voltage gated channels occur. The axon is insulated so the action potential at one node is sufficient to trigger an action potential in the next node and the impulse jumps along the fibre. This differs from impulse transmission in a non-myelinated neuron in which voltage-gated channels occur along the entire length of the axon.

As well as increasing the speed of conduction, the myelin sheath reduces energy expenditure because the area over which depolarization occurs is less (and therefore the number of sodium and potassium ions that need to be pumped to restore the resting potential is fewer).



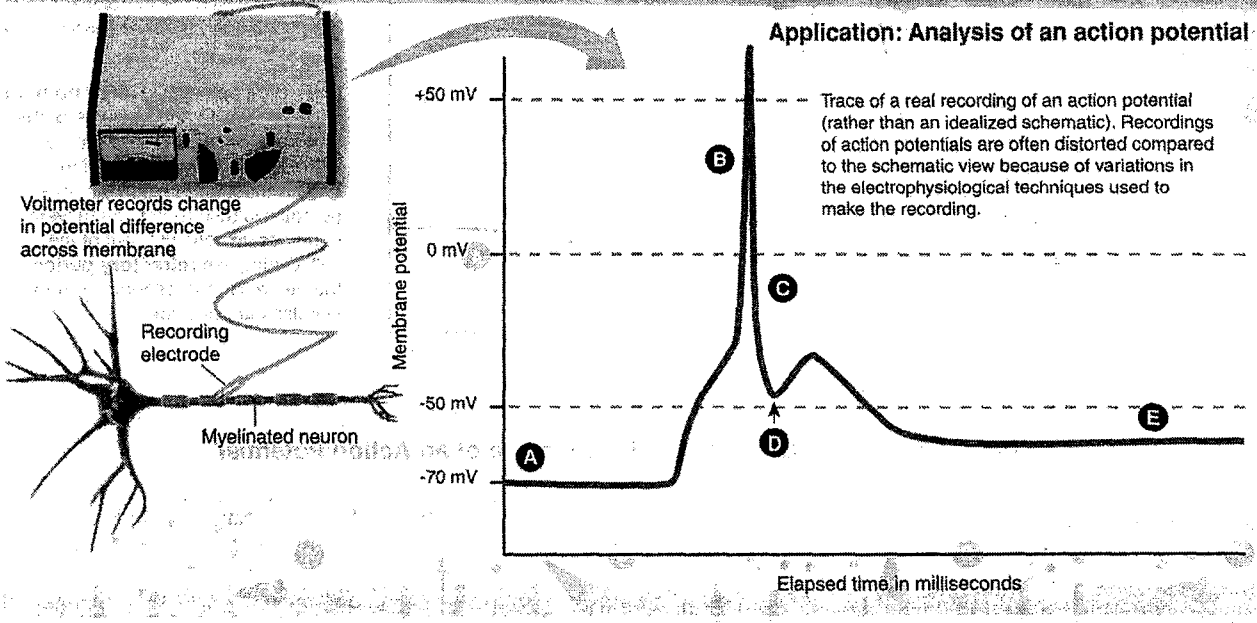
1. What is an action potential? _____

_____

2. (a) What occurs during saltatory conduction? _____

_____

(b) What influence does this have on conduction speed? _____

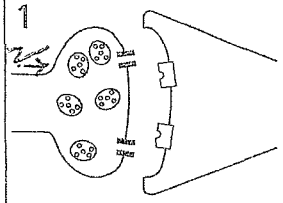
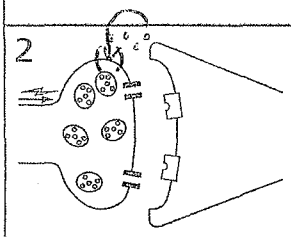
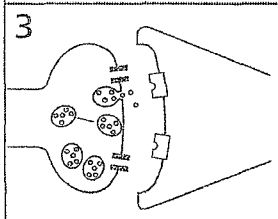
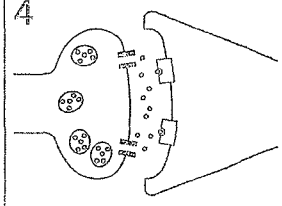
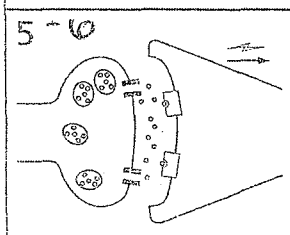
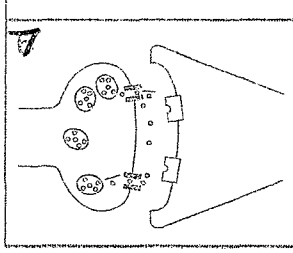


3. The graph above shows a recording of the changes in membrane potential in an axon during transmission of an action potential. Match each stage (A-E) to the correct summary provided below.

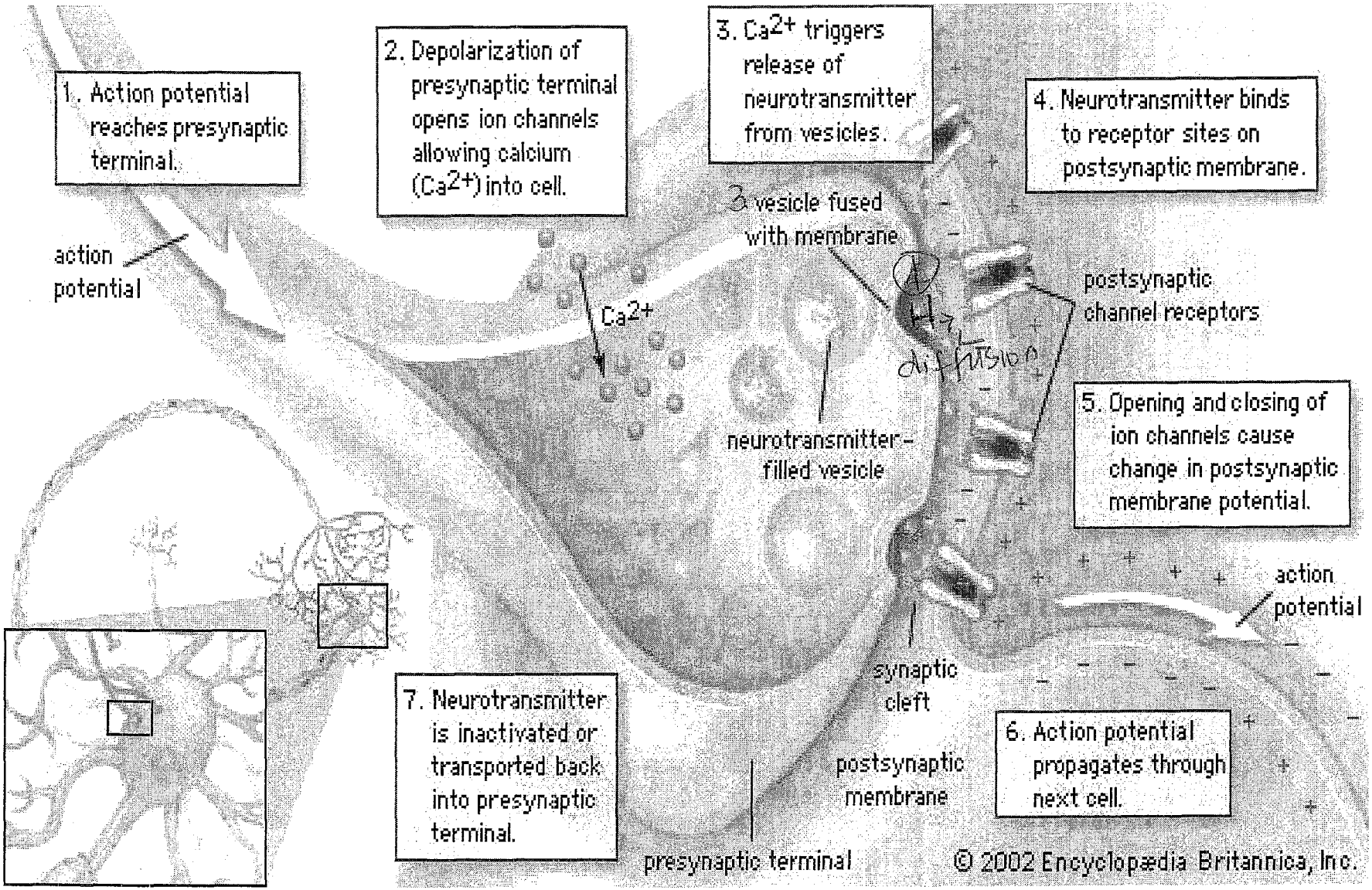
- ☐ Membrane depolarization (due to rapid Na^+ entry across the axon membrane.
- ☐ Hyperpolarization (an overshoot caused by the delay in closing of the K^+ channels.
- ☐ Return to resting potential after the stimulus has passed.
- ☐ Repolarization as the Na^+ channels close and slower K^+ channels begin to open.
- ☐ The membrane's resting potential.

How Do Neurons Communicate?

Name(s)_____ Date_____

1 	
2 	
3 	
4 	
5 - 6 	
7 	

SYNAPTIC TRANSMISSION

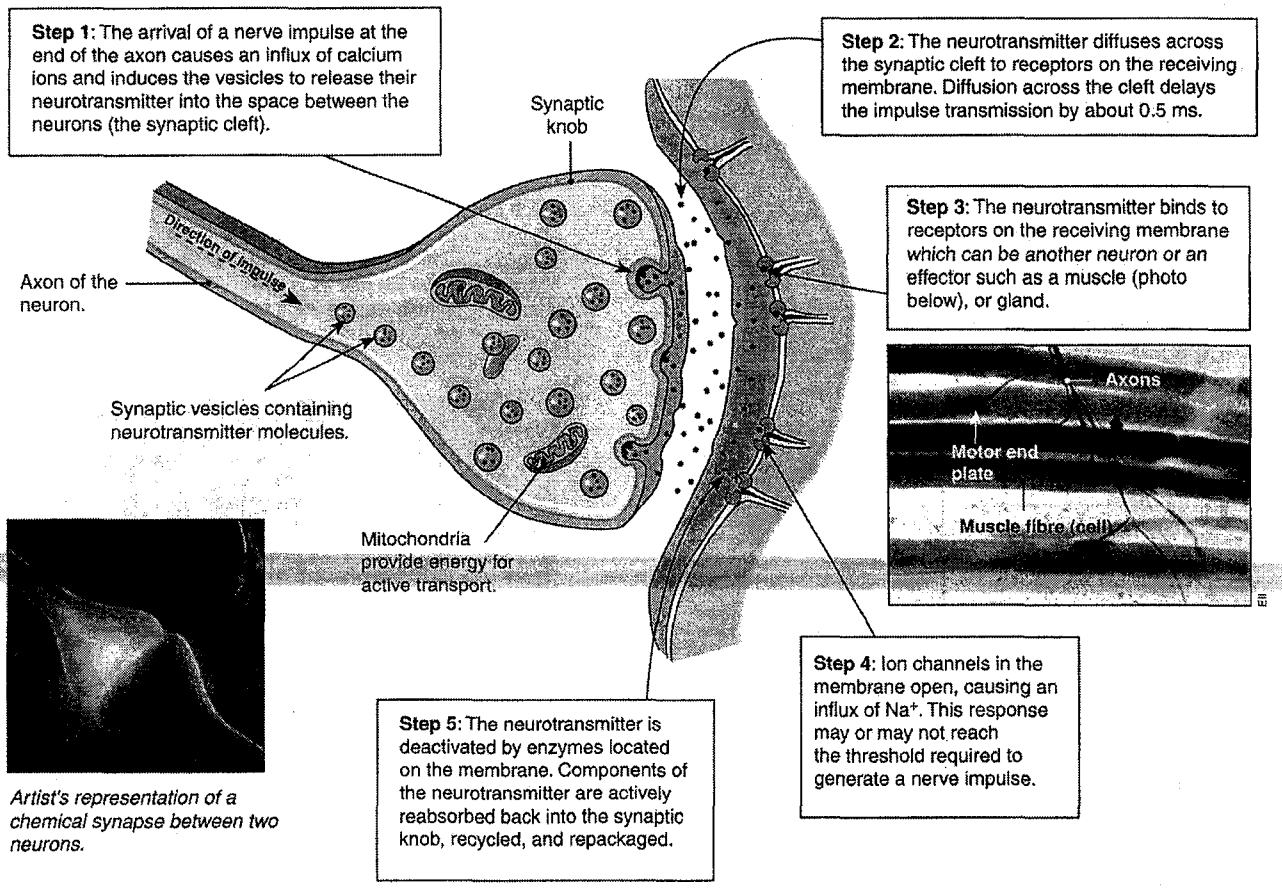


195 Chemical Synapses

Key idea: Chemical synapses are junctions between neurons, or between neurons and receptor or effector cells.

Action potentials are transmitted across junctions called **synapses**. Synapses can occur between two neurons, or between a neuron and an effector cell (e.g. muscle or gland). The axon terminal is a swollen knob, and a small gap (synaptic cleft) separates it from the receiving neuron. The synaptic knobs are filled with tiny packets of chemicals called **neurotransmitters**. The neurotransmitter diffuses across the gap, where it interacts with the receiving (post-synaptic) membrane and causes an electrical response. In the example below, the neurotransmitter causes a membrane depolarization and the generation of an action potential. Some neurotransmitters have the opposite effect and cause inhibition (e.g. slowing heart rate). Chemical synapses are the most widespread type of synapse in nervous systems.

The Structure of a Chemical Synapse



Artist's representation of a chemical synapse between two neurons.

1. What is a **synapse**? _____

2. What causes the release of neurotransmitter into the synaptic cleft? _____

3. Why is there a brief delay in transmitting an impulse across the synapse? _____

4. (a) How is the neurotransmitter deactivated? _____

   (b) Why is it important for the neurotransmitter substance to be deactivated soon after its release? _____

5. Suggest one factor that might influence the strength of the response in the receiving cell: _____

Name:_____ Date:_____

Reading Comprehension Strategies: PROBLEM/SOLUTION CHART

Directions: Before you read the following passage, think about focusing on these four critical areas to problem-solving:

-identifying the problem - listing the consequences or results of that problem - isolating the causes and proposing solutions.

As you read the passage, underline important text that may help you to address these critical areas.

Discuss your thoughts with you group and complete the chart on the back of this page.

Neonicotinoids

Blocking of synaptic transmission at cholinergic synapses in insects by binding of neonicotinoid pesticides to acetylcholine receptors.

Neonicotinoids are synthetic compounds similar to nicotine. They bind to the acetylcholine receptor in cholinergic synapses in the central nervous system of insects. Acetylcholinesterase does not break down neonicotinoids, so the binding is irreversible. The receptors are blocked, so acetylcholine is unable to bind and synaptic transmission is prevented. The consequence in insects is paralysis and death. Neonicotinoids are therefore very effective insecticides.

One of the advantages of neonicotinoids as pesticides is that they are not highly toxic to humans and other mammals. This is because a much greater proportion of synapses in the central nervous system are cholinergic in insects than in mammals and also because neonicotinoids bind much less strongly to acetylcholine receptors in mammals than insects.

Neonicotinoid pesticides are now used on huge areas of crops. In particular one neonicotinoid, imidacloprid, is the most widely used insecticide in the world. However, concerns have been raised about the effects of these insecticides on honeybees and other beneficial insects. There has been considerable controversy over this and the evidence of harm is disputed by the manufacturers and some government agencies.

Problem-Solution Chart

What is The Problem?	
What Are The Effects?	
What Are The Causes?	
What Are Some Possible Solutions?	

Name:_____ Date:_____

As we initially read the short passage please react to the reading by **annotating** on the **right** side of the page. These can be questions, thoughts, or personal connections to the text. With a partner you will share and discuss your reactions.

You will then number (CHUNK) each paragraph and reread the text together. Underline **only** important vocabulary or concepts. Stop after each paragraph and summarize the GIST of the paragraph. Address the 5 w's- who, what, where, when, and how.

GIST	Reactions to
Summarize the 5 W's	Text

Research into memory and learning

Cooperation and collaboration between groups of scientists: biologists are contributing to research into memory and learning.

Higher functions of the brain including memory and learning are only partly understood at present and are being researched very actively. They have traditionally been investigated by psychologists but increasingly the techniques of molecular biology and biochemistry are being used to unravel the mechanisms at work. Other branches of science are also making important contributions, including biophysics, medicine, pharmacology and computer science.

The Centre for Neural Circuits and Behaviour at Oxford University is an excellent example of collaboration between scientists with different areas of expertise. The four group leaders of the research team and the area of science that they originally studied are:

- Professor Gero Miesenböck – medicine and physiology
- Dr Martin Booth – engineering and optical microscopy
- Dr Korneel Hens – chemistry and biochemistry
- Professor Scott Waddell – genetics, molecular biology and neurobiology.

Continue on back-→

https://www.youtube.com/watch?v=8tJPJBbUTDc
Memory and Learning and cooperation and collaberation

The centre specializes in research techniques known as optogenetics. Neurons are genetically engineered to emit light during synaptic transmission or an action potential, making activity in specific neurons in brain tissue visible. They are also engineered so specific neurons in brain tissue respond to a light signal with an action potential. This allows patterns of activity in the neurons of living brain tissue to be studied.

There are many research groups in universities throughout the world that are investigating memory, learning and other brain functions. Although there is sometimes competition between scientists to be the first group to make a discovery, there is also a strongly collaborative element to scientific research. This extends across scientific disciplines and national boundaries. Success in understanding how the brain works will undoubtedly be the achievement of many groups of scientists in many countries throughout the world.

Summarize the **Research into Memory and Learning** passage:

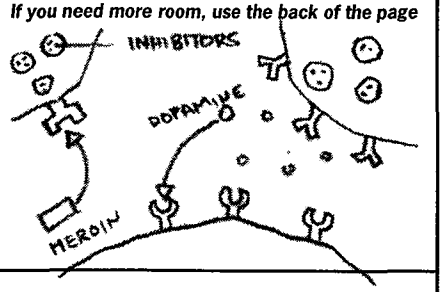
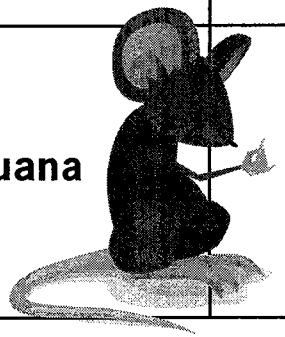
https://www.youtube.com/watch?v=8tJPJBbUTDc
Memory and Learning and cooperation and collaberation

Name _____

Date _____

Mouse Party Neural Data Matrix

Log on to *http://gslc.genetics.utah.edu/units/addiction* and observe the Mouse Party. Fill in the table below, creating a sketch that summarizes the action of each drug in the "Summary Illustration" column.

Drug	Neurotransmitter(s) Involved	Action of Drug	Summary Illustration
 **Heroin**			*If you need more room, use the back of the page* 
Ecstasy			
Marijuana 			

6.5 S.1 Analysis of oscilloscope traces showing resting potentials and action potentials.

Neuron Simulation lab (Slide 25)

Go to http://phet.colorado.edu/en/simulation/neuron and click 'Run now".
Use this link if you need help: http://en.wikipedia.org/wiki/Neuron

This is a simulation of the axon of a neuron. Let's figure out how nerve signals travel down the length of the axon.

1. Zoom in on the neuron. What protein structures are imbedded in the membrane?

2. What substance is there more of outside the neuron? What about inside? (Click "Show concentrations" if you are unsure).

3. a. What is the charge of the inside of the cell? (Click "Show charge"

   b. What is the charge of the outside of the cell?

   c. If K+ and Na+ are both positive, how might a negative charge come about?

4. Zoom out and slow the sim down. Click "Stimulate neuron". Holy cow! Describe what you saw.

5. a. Which way did Na+ move? Through what did it move to get there?

   b. Which way did K+ move? Through what did it move to get there?

   c. What was the wave that moved down the neuron?

   d. Why did the K+ and Na+ move?

   e. Describe what happens to the charge on the inside and outside after the wave passes.

6. Can you stimulate the neuron again right after firing it? Why?

7. Click the button "Potential chart" Stimulate the neuron and draw the resulting graph below. Label "threshold", "stimulus", "resting potential" and "undershoot" on your graph. Make the title "Action Potential"

a. What does this graph show?

8. Is there a way to make the signal any stronger? Is there a way to make it stronger in an actual neuron?

9. What is the myelin sheath? Does this simulation have one?

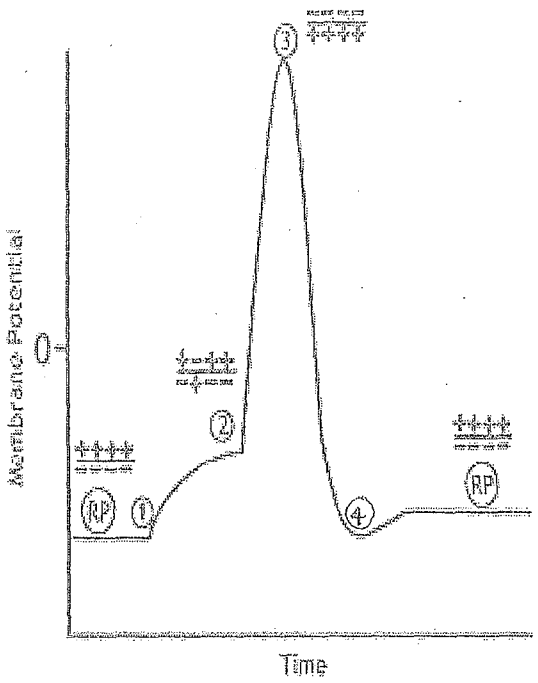
10. How would the signal be different if there was a myelin sheath?

11. Pinch yourself. How fast does this process actually go in your neurons?

12. How is this simulation similar to and different from an actual neuron?

13. How does the signal travel from one neuron to the next? (not in simulation)

Nerve Transmission



This graph shows how the cell potential changes at the resting potential (RP) and each of the 3 stages of nerve signal transmission in the previous list. The inset images show how the ions are arranged at the cell membrane (inside the cell is on the bottom).

Summarize what is happening at each of the following points during the action potential:

RP: _____

_____

_____

_____

1: _____

_____

_____

_____

2: _____

_____

_____

_____

3: _____

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4: _____

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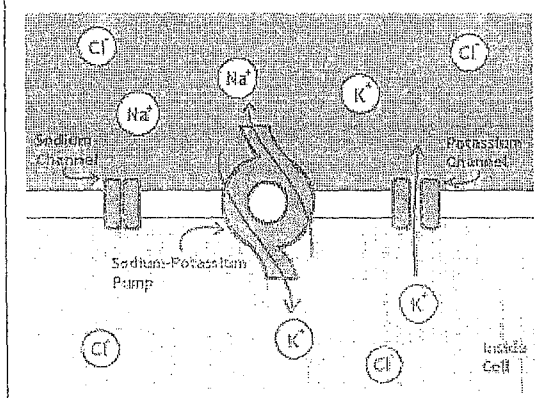
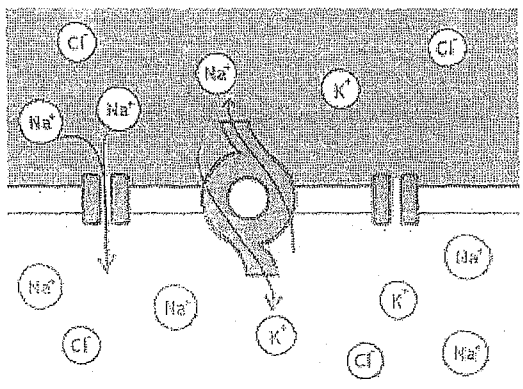


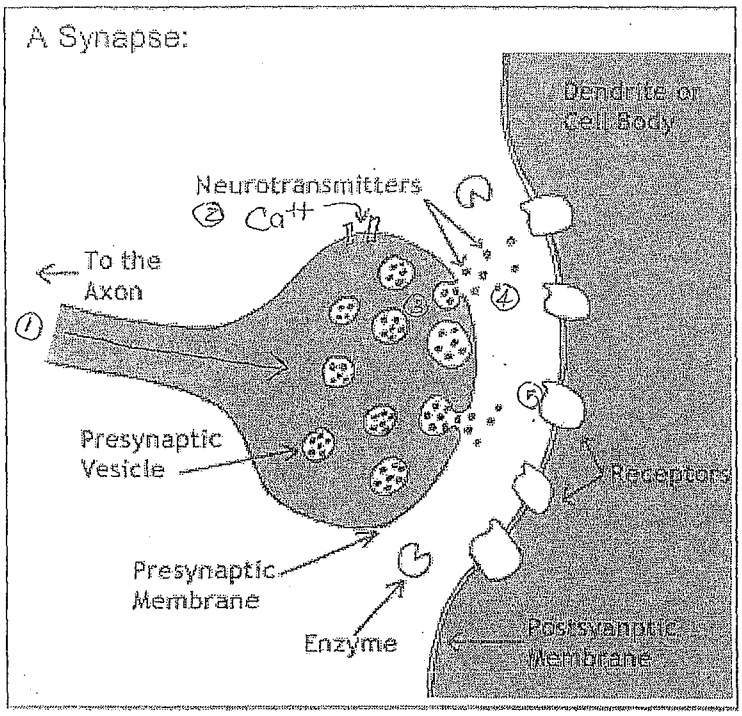
At the resting potential, the sodium channels are closed, and there are more positive ions outside the cell than inside.



At the action potential, the sodium gates are open, and sodium is moving into the cell. For a short time, there are more positive ions inside the cell than outside.

Name:_____ Date:_____

Synaptic Transmission



When the action potential arrives at the presynaptic membrane, it causes calcium ions (Ca2+) to move across the membrane and into the cell. The increased calcium concentration causes molecules called neurotransmitters to be released through the presynaptic membrane into the gap. The neurotransmitters move across the synaptic cleft and reach receptor molecules on the postsynaptic membrane. When a neurotransmitter triggers one of the receptors, it causes a reaction in the second cell that can start an action potential.

Summarize each step of SYNAPTIC TRANSMISSION:

1._____

2._____

3._____

4._____

5._____

Neurotransmitters in the synaptic cleft is broken down by enzymes in the synaptic cleft, and some parts of the molecules are taken back into the nerve cell to be recycled.

http://library.vcc.ca/learningcentre/pdf/worksheets/biology-nerve_signal_transmission-2007.pdf