Nervous System: C11. Analyze the transmission of nerve impulses

1. Identify the 3 main parts of the neuron (dendrite, cell body, axon).

2. Complete the table.

<table>
<thead>
<tr>
<th>Name of Structure</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>dendrite</td>
<td>Receives signal and conduct the nerve impulse TOWARDS the cell body</td>
</tr>
<tr>
<td>cell body</td>
<td>Controls and maintains the cell because it contains the nucleus</td>
</tr>
<tr>
<td>axon</td>
<td>Conducts the nerve impulse AWAY from the cell body</td>
</tr>
</tbody>
</table>

3. Identify the 3 types of neurons as well as X & Y in the diagram.
4. Differentiate among sensory, motor, and interneuron by completing the table.

<table>
<thead>
<tr>
<th>Name of Neuron</th>
<th>Diagram</th>
<th>Location</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensory neuron</td>
<td><img src="image1.png" alt="Sensory neuron diagram" /></td>
<td>Peripheral nervous system (PNS) and Central nervous system (CNS)</td>
<td>Carries the message (nerve impulse) from the sensory receptor to the CNS</td>
</tr>
<tr>
<td>Interneuron</td>
<td><img src="image2.png" alt="Interneuron diagram" /></td>
<td>CNS only</td>
<td>Receives the nerve impulse from the sensory neuron and sends the impulse to the brain and motor neuron.</td>
</tr>
<tr>
<td>Motor neuron</td>
<td><img src="image3.png" alt="Motor neuron diagram" /></td>
<td>CNS &amp; PNS</td>
<td>Carries the nerve impulse / message from the interneuron to an effector (muscle or gland)</td>
</tr>
</tbody>
</table>

5. Identify the parts of the reflex arc in the diagram and explain what a reflex is.

A reflex is an involuntary, automatic response to a large stimulus. It just happens; there is no need to think about it.
6. What is a dorsal-root ganglion?

A collection of sensory neuron cell bodies that are located along the vertebral column by the spine

7. Relate the structure of a myelinated nerve fibre to the speed of impulse conduction, with reference to myelin sheath, Schwann cell, node of Ranvier, and saltatory transmission.

- Myelin is a fatty substance wrapped around some nerve fibres to form what is called the myelin sheath. Myelin is produced by Schwann cells (a neuroglia cell).
- The myelin sheath speeds up the nerve impulse by causing saltatory conduction / transmission to occur where the impulse jumps from one node of Ranvier to the next node of Ranvier.
- The nodes of Ranvier is a place on the nerve fibre where there is no myelin and are the points between Schwann cells.

**Action Potential**

8. Explain the transmission of a nerve impulse through a neuron, using the following terms:

- resting and action potential
- refractory period
- depolarization and repolarization
- sodium and potassium gates
- axoplasm
- polarity
- sodium-potassium

Nerve impulse = resting potential + action potential

**Resting Potential:** outside of the neuron is positive, the inside of the neuron (axoplasm) is negative due to the distribution of Na\(^+\), K\(^+\), and negative ions.

- At rest, there is more K\(^+\) inside and more Na\(^+\) outside of the neuron.

- At rest, sodium and potassium gates are closed so these ions cannot move

**Depolarization:** If the stimulus reaches the threshold level of -40mV, the sodium gates open and Na\(^+\) enters the neuron and joins K\(^+\) in the axoplasm.

- There are now more positive ions than negative ions inside the axoplasm so the polarity changes to positive inside and negative outside.

**Repolarization:** When the voltage reaches +40mV, the K\(^+\) gates open and K\(^+\) leaves the neuron and goes to the outside.

- The polarity now changes again and the axoplasm goes back to being negative and the outside of the neuron is positive again.

- The Na\(^+\) gates are closed during repolarization.

**Refractory Period:** recovery phase. The Na\(^+\) & K\(^+\) voltage gated ion channels close during the refractory period.

- The sodium-potassium pump resets the neuron for the next nerve impulse by pumping K\(^+\) back into the axoplasm and Na\(^+\) back outside of the neuron.

- The neuron has now re-established the resting condition so the neuron can receive another nerve impulse.
9. What is the sodium-potassium pump? In what phase of the action potential is it active?
   It is a form of active transport requiring ATP. There is a carrier protein that actively moves Na+ outside of the cell and K+ into the cell. This restores the original conditions of the resting potential.
   It occurs during the refractory period

10. What is diffusion?
   The movement of a substance from high to low concentration

11. What is an oscilloscope?
   A voltmeter that measures the potential difference across the axomembrane of a neuron.

12. What is an action potential?
   A rapid change in the polarity across an axomembrane as the nerve impulse is conducted along the neuron

13. What are sodium gates? When do the sodium gates open?
   Sodium gates are proteins that allow Na+ to move across the axomembrane. The sodium gates open during depolarization (-65mV to +40mV).

14. What are potassium gates? When do the potassium gates open?
   Potassium gates are proteins that allow K+ to move across the axomembrane. The potassium gates open during repolarization (+40mV to -70mV).

15. Nerve impulse – Action potential

<table>
<thead>
<tr>
<th></th>
<th>Range of mV</th>
<th>Charge inside the neuron</th>
<th>Charge outside the neuron</th>
<th>Describe Na⁺ and K⁺ concentrations or movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resting potential</td>
<td>-65 mV</td>
<td>Negative</td>
<td>Positive</td>
<td>Na⁺ greater outside the neuron K⁺ greater inside the neuron</td>
</tr>
<tr>
<td>Depolarization</td>
<td>-65 mV to +40 mV</td>
<td>Positive</td>
<td>Negative</td>
<td>Na⁺ moves inside neuron and joins K⁺ still inside the neuron</td>
</tr>
<tr>
<td>Repolarization</td>
<td>+40 mV to -65 mV</td>
<td>Negative</td>
<td>Positive</td>
<td>Na⁺ stays inside the neuron K⁺ moves outside of the neuron</td>
</tr>
<tr>
<td>Refractory period</td>
<td>-70 mV to -65 mV</td>
<td>Negative</td>
<td>Positive</td>
<td>Na⁺ greater outside the neuron K⁺ greater inside the neuron</td>
</tr>
</tbody>
</table>
16. On the following nerve impulse label:

a) Threshold
b) Resting potential
c) Depolarization
d) Repolarization
e) Action potential
f) Refractory period
g) When sodium ions move inside
h) When potassium ions move outside
i) When Na+/K+ pump in action

17. During the refractory period, why are the sodium and potassium gates unable to open for a brief amount of time?

So the action potential cannot move backwards

18. Put the following statements in proper order.

___3____ Membrane is depolarized
___4____ Potassium gates open
___6____ Sodium-potassium pump restores resting potential
___5____ Sodium is inside neuron, potassium is outside
___1____ Sodium is outside neuron, potassium is inside
___2____ Sodium gates open
19. Explain what is happening in the following diagrams

**Explanation:**

**Resting potential:**
No nerve impulse therefore, no movement of ions.

Na+ greater outside the neuron while K+ is greater inside the neuron.

**Sodium gates open:**
The membrane potential changes to +40 mV inside the axon (axoplasm).
This causes depolarization to occur

**Potassium gates open:**
The membrane potential goes back to -65 mV inside the axon.
This causes repolarization to occur
20. **What is a synapse?**

- Space / area where an axon bulb of one neuron and the postsynaptic cell (dendrite, muscle or gland) are close together but not touching.
- It allows the nerve impulse (electrical) to be transmitted to the next neuron (chemically with neurotransmitters).

21. **Explain the concepts of threshold, ‘all or none’ response, inhibitory and excitatory neurotransmitters, and summation as they relate to synaptic transmission.**

- **Threshold** = the minimum amount of stimuli required to produce a nerve impulse. All the excitatory and inhibitory signals on the dendrite (from inhibitory and excitatory neurotransmitters) are integrated (summed up) to determine if the neuron will fire or not.
- As long as the threshold stimulus of -40 mV has been reached, there will be an impulse. So, the neuron fires or not. There is no half impulse created. The impulse is always the same size. This is the all or none response.

22. **Label these major components of a synapse:** presynaptic membrane, postsynaptic membrane, synaptic cleft, synaptic vesicle, axon bulb, neurotransmitter, calcium ions and contractile proteins.

23. **What is a neurotransmitter?**

Molecules / chemicals stored in the axon bulb that are responsible for synaptic transmission (linking nerve impulse to next neuron).

24. **Number the following events for synaptic transmission in the correct order**

   _6_ An action potential is stimulated at the postsynaptic membrane and impulse travels down dendrite
   _7_ An enzyme cleaves the neurotransmitter substance and clears out the synaptic cleft
   _1_ Impulse reaches synapse from the axon
   _2_ Impulse stimulates synaptic vesicles to move to presynaptic membrane
   _4_ Neurotransmitter substance diffuses across the cleft
   _5_ Neurotransmitter substance fits into receptor sites on postsynaptic membrane
   _3_ Synaptic vesicles dump neurotransmitter substance into synaptic cleft
25. What is exocytosis? Where does it occur in synaptic transmission?
• Where a vesicle, inside the neuron’s axon bulb, fuses with the plasma membrane and releases its contents outside of the cell and into the synaptic cleft/gap.
• Exocytosis occurs in the axon bulb.

26. A) Name the enzyme that breaks down acetylcholine

Acetylcholinesterase (AchE)

B) Name the enzyme that breaks down norepinephrine/noradrenalin

Monoamine oxidase

27. If the neurotransmitter is not broken down by an enzyme, what happens to it?

It is rapidly reabsorbed by the presynaptic membrane and recycler molecules can be involved to help with this process.

28. Why is a neurotransmitter in the synaptic cleft for only a short period of time?

It is broken down by enzymes or taken back up by endocytosis by the presynaptic cell.

It prevents constant stimulation of the postsynaptic membrane.

29. Why would the axon bulb have mitochondria?

• Exocytosis = active transport and therefore need ATP. ATP is made by the mitochondria. Therefore, the axon bulb also has lots of mitochondria.

• Calcium ions are also returned by active transport so cell needs ATP

30. How does the design of a synapse ensure nerve impulses travel in one direction?

Because the neurotransmitter is only released from the presynaptic membrane (axon bulb) and the receptors for the neurotransmitter are only on the postsynaptic membrane (dendrite). This ensures that the nerve impulse travels in only one direction.
Transmission of a Nerve Impulse

Depolarization of membrane to the threshold level

Voltage-sensitive sodium channels open

sodium enters the neuron (cell)

ACTION POTENTIAL

sodium gates close: potassium gates open

action potential travels to axon bulb

depolarization of synaptic membrane

Calcium channels open; calcium enters the neuron (cell)

CHEMICAL SYNAPSE

neurotransmitter is released into synaptic cleft

neurotransmitter binds to receptors on post synaptic membrane

excitatory synaptic vesicles fuse with membrane

Specific ion channels open: membrane receives excitatory and/or inhibitory signals

Enzymes cleave/breakdown neurotransmitter or it is reabsorbed by the presynaptic membrane

Integrate determines if action potential is generated

resting potential returns

potassium flows out, repolarizing the membrane

Word bank: sodium, potassium, pre, post, resting, depolarizing, repolarizing, threshold, axon bulb, enzymes, integration, neurotransmitter, excitatory, calcium (used 2 X)
31. What are the two main divisions of the nervous system and describe their function(s)?

- **Central nervous system (CNS)** - control centre, integrates sensory information and formulates response
- **Peripheral nervous system (PNS)** – gathers stimuli, relays it to CNS, and relays response to appropriate effector

32. What are the two main parts of the central nervous system?

Brain and spinal cord

33. What is the job of the central nervous system?

Control centre – receives the sensory input from the PNS and integrates / formulates the response(s) (if any) to the stimuli detected

34. What is the function of the peripheral nervous system?

- Carries information between the CNS and the body; gathers stimuli, relays it to CNS, and relays response to appropriate effector

35. Complete the chart to compare the effects of the sympathetic and parasympathetic divisions of the autonomic nervous system.

<table>
<thead>
<tr>
<th>Body Function</th>
<th>Sympathetic NS</th>
<th>Parasympathetic NS</th>
</tr>
</thead>
<tbody>
<tr>
<td>heart rate</td>
<td>Increases</td>
<td>Decreases</td>
</tr>
<tr>
<td>breathing rate</td>
<td>Increases</td>
<td>Decreases</td>
</tr>
<tr>
<td>pupil size</td>
<td>Dialate</td>
<td>Constrict</td>
</tr>
<tr>
<td>digestion</td>
<td>Decreases / stops</td>
<td>Increases / starts</td>
</tr>
<tr>
<td>neurotransmitter</td>
<td>Noradrenalin</td>
<td>Acetylcholine</td>
</tr>
<tr>
<td>overall response</td>
<td>“fight or flight”</td>
<td>relaxed state</td>
</tr>
</tbody>
</table>

36. What is the source gland for adrenalin? Explain its role in the “fight or flight” response.

- Adrenal gland makes adrenalin
- Adrenalin is involved in the “fight or flight” response by increasing the activity of the receiving cells / tissues / organs (except the digestive system)
- Examples – increase heart rate, breathing rate, blood pressure, decreases digestion.
37. What are ventricles?
Spaces / cavities in the brain that are connected which produce and store cerebral spinal fluid. There are 4 of them.

38. What is the function of the midbrain?
It acts as a relay station for tracts passing to the cerebrum and spinal cord / cerebellum. It also has the reflex centres for vision, hearting (auditory), and tactile responses.

39. Complete the table and identify the parts on the diagram.

<table>
<thead>
<tr>
<th>Structure</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>medulla oblongata</td>
<td>Vital centres – regulates heartbeat, breathing &amp; vasoconstriction. Has reflex centres for vomiting, coughing, sneezing, hiccupping &amp; swallowing.</td>
</tr>
<tr>
<td>cerebrum</td>
<td>Responsible for consciousness and higher level mental function. Receives sensory input and carries out integration and coordinates responses.</td>
</tr>
<tr>
<td>thalamus</td>
<td>“sorting centre” that directs input to the proper region of the brain for interpretation.</td>
</tr>
<tr>
<td>cerebellum</td>
<td>Maintains muscle tone, posture, balance and coordination.</td>
</tr>
<tr>
<td>hypothalamus</td>
<td>Maintains homeostasis by regulating hunger, sleep, thirst, body temperature and (hormones). It also directly controls the pituitary gland (anterior &amp; posterior).</td>
</tr>
<tr>
<td>anterior pituitary gland</td>
<td>It has some control over hormones. Such as ADH &amp; oxytocin.</td>
</tr>
<tr>
<td>posterior pituitary gland</td>
<td>It allows secretion of hormones.</td>
</tr>
<tr>
<td>meninges</td>
<td>Protect and cushion</td>
</tr>
<tr>
<td>skull</td>
<td></td>
</tr>
<tr>
<td>cerebrum</td>
<td></td>
</tr>
<tr>
<td>Corpus callosum</td>
<td></td>
</tr>
<tr>
<td>cerebellum</td>
<td></td>
</tr>
<tr>
<td>spinal cord</td>
<td></td>
</tr>
<tr>
<td>medulla oblongata</td>
<td></td>
</tr>
</tbody>
</table>
41. Explain how the hypothalamus and pituitary gland interact as the neuroendocrine control centre.

- The hypothalamus is the part of the brain that has control over the internal organs.
- It samples the blood that travels through it and causes the anterior & / or posterior pituitary glands to release hormones to influence and regulate other organs of the body.

42. Label the lobes

![Brain lobes diagram](image)