SUGGESTED TEXTBOOK ANSWERS

Chapter 3 Nerve cells and nerve impulses

The following are suggested answers only. Other answers to the same questions may also be correct.

Science inquiry

Activity 3.1 A neuron tour

Imagine that you are the size of a sodium ion and that you have been given the task of taking a group of tiny tourists on a guided tour of a motor neuron. You need to write a commentary to use on your tour.

Answer: Key points that students should include in their answers:

- You enter the cell through the cell membrane.
- You are now inside the dendrite, which is a long, narrow strand of cytoplasm.
- The dendrite carries nerve impulses towards the body of the cell.
- You move along the dendrite into a large mass of cytoplasm, which is the cell body.
- In the cell body you can see the nucleus, mitochondria, endoplasmic reticulum, ribosomes, Golgi apparatus and other organelles (encourage students to describe each of the organelles)
- You leave the cell body through a very long corridor of cytoplasm – the axon.
- The axon carries nerve impulses away from the cell body.
- You continue along the axon for a considerable length.
- Students may mention being able to see the myelin sheath and nodes of Ranvier through the membrane of the axon.
- Near the end of the axon, you move into a small branch and end up in a slightly enlarged area – the axon terminal.
- You move through the membrane of the axon terminal to exit the neuron.
- Upon leaving the axon, the tour group can see, in the distance, some muscle fibres.

Activity 3.2 A model of a neuron

Label all the structures that make up your model of a neuron. Be prepared to explain the functions of the various parts of your model to other class members.

Answer: Some points to look for when evaluating students' models include the following:

- The model is that of a multipolar neuron, and it does have a myelin sheath.
- Materials chosen for the model are appropriate to their function.
- The relative size of different parts of the model are correct.
- There is accuracy in representing the various parts of the neuron.
- All parts are correctly labelled.

Activity 3.3 The discovery of neurotransmitters

1 Explain how the result of Loewi's experiment enabled him to claim that a chemical was involved in slowing the rate of beating of the hearts.

Answer: There was nothing else that had changed to cause heart B to beat more slowly. There was no connection between heart A and B, except the transfer of salt solution from container A to B. Heart B had the vagus nerve removed so there could have been no nerve stimulation.

2 Would Loewi have got the same result if he had placed both hearts in the same beaker of salt solution?

Answer: Probably – because the chemical from heart A would have diffused into the solution and affected heart B.

3 What control experiments would have been necessary before Loewi could claim that a chemical secreted by nerve cells was involved in slowing the hearts?

Answer: Loewi would need to show that heart B did not slow naturally in the absence of salt solution from heart A. He could also have taken salt solution from around a heart that was slowing without any nervous stimulation and see whether that solution had any effect on a second heart.

4 Loewi called the chemical 'vagusstoff' (or 'vagus stuff' when translated into English). What do we now call the neurotransmitter released at neuromuscular junctions?

Answer: Acetylcholine

5 If Loewi was doing such an experiment today, what do you think he would write down as his:

a hypothesis

Answer: Possible hypotheses could be:

- that vagusstoff slows the heart rate
- that a chemical produced by the vagus nerve slows the heart rate
- that a chemical produced at nerve endings can affect the heart rate.

b testable prediction?

Answer: Possible predictions could include the following:

- The heart will slow down in the presence of a chemical secreted by the vagus nerve.
- A chemical released when one heart slows due to nervous stimulation will, if applied to a second heart, cause the second heart to slow.

Review questions

1 Explain the difference between the central nervous system and the peripheral nervous system.

Answer: The central nervous system is the control centre for the whole nervous system. It consists of the brain and spinal cord.

The nerves that connect the CNS with muscles, glands, receptors and other organs make up the peripheral nervous system. The nerves carry messages between the organs and the CNS.

2 a Explain the difference between a myelinated fibre and an unmyelinated fibre.

Answer: Myelinated nerve fibres are covered with a myelin sheath of fatty material; unmyelinated fibres do not have this covering.

b Describe how the sheath of a myelinated fibre is formed.

Answer: In fibres outside the brain and spinal cord, the myelin sheath is formed by Schwann cells that wrap around the axon and deposit layers of myelin between each coil.

3 Depending on their functions there are three different types of neuron. Name the three types and describe the function of each.

Answer: The three different types of neuron are as follows:

- Sensory (or receptor) neurons, which carry messages from receptors in the sense organs, or in the skin, to the central nervous system (brain and spinal cord).
- Motor (or effector) neurons, which carry messages from the central nervous system to the muscles and glands – the effectors.
- Interneurons, which are located in the central nervous system. They are the link between the sensory and motor neurons (these may also be called association neurons, connector neurons or relay neurons).

4 Explain the difference between multipolar, bipolar and unipolar neurons. In what part of the nervous system is each type of neuron found?

Answer: Multipolar neurons have one axon and many dendrites extending from the cell body. They include most of the interneurons in the brain and spinal cord and also the motor neurons that carry messages to the skeletal muscles.

Bipolar neurons have one axon and one dendrite each of which may have many branches at their ends. Bipolar neurons occur in the eye, ear and nose, where they transfer impulses from the receptor cells to other neurons.

Unipolar neurons have only one extension, an axon with the cell body located to one side of the axon. Most sensory neurons that carry messages to the spinal cord are of this type.

5 Explain the difference between a neuron, a nerve and a nerve fibre.

Answer: A neuron is the scientific name for a nerve cell. A nerve fibre is any long extension of cytoplasm from a nerve cell body (usually refers to an axon). A nerve is a bundle of nerve fibres that are held together by connective tissue.

6 a Define 'electrical potential'.

Answer: Positive and negative electrical charges attract each other. There is an electrical force that tends to pull them together. If a group of positive and negative charges are separated they have the potential to come together and release energy. This is called the electrical potential, or potential difference.

b What is the potential of the membrane of a nerve cell when it is not conducting a nerve impulse?

Answer: The membrane potential of an unstimulated nerve cell is approximately –70 millivolts (mV). That is, the potential of the inside of the membrane is 70 mV less than that of the outside.

7 Explain how the potential of a resting nerve cell membrane is maintained.

Answer: The resting membrane potential of neurons occurs because the distribution of potassium ions (K^+) and sodium ions (Na^+) on either side of the cell membrane is different. The cell membrane maintains the potential difference in two ways. First, by a sodium–potassium pump that transports sodium ions out of the cell and potassium ions in. Second, there are large numbers of negatively charged ions trapped inside the cell because the cell membrane is not equally permeable to all ions. There are not enough of the positively charged potassium ions inside the cell to balance the effect of the large number of negative ions. Thus, the inside of the membrane is negative in relation to the outside – the membrane has a resting potential.

8 a Define 'action potential'.

Answer: An action potential is a rapid depolarisation/repolarisation of the membrane of a nerve cell. When a nerve cell membrane is stimulated sodium ions move into the cell so that the membrane is depolarised. Very quickly, the membrane is then restored to its original condition – it is repolarised.

b Formation of an action potential is an all-or-none response. Define 'all-or-none response'.

Answer: An all-or-none response is where the size of the response is not related to the strength of the stimulus. If the stimulus on the nerve cell membrane is large enough to cause a change of 15 mV then the movement of sodium ions is independent of the stimulus. The magnitude of the response does not depend on the strength of the stimulus.

9 What is the 'refractory period' of an action potential?

Answer: During the refractory period of an action potential, the nerve fibre cannot be stimulated to respond again. It occurs during the action potential itself and for a short time afterwards.

10 a Explain how a nerve impulse passes along a nerve fibre.

Answer: Each action potential generates another action potential just in front of it. Thus the nerve impulse passes along the nerve fibre as successive action potentials.

b Explain the difference between the way a nerve impulse is conducted along a myelinated and an unmyelinated nerve fibre.

Answer: In an unmyelinated nerve fibre, a stimulus causes depolarisation of an area of the membrane. Depolarisation then occurs immediately adjacent to the site of the original stimulus. The process repeats itself along the whole length of the membrane so that the impulse moves along the membrane away from the point of stimulation.

Myelinated fibres have gaps in the myelin sheath called nodes of Ranvier. The myelin sheath insulates the fibre from the extracellular fluid so that ions cannot flow between the inside and outside of the membrane, and an action potential cannot form. In a myelinated fibre, the action potential jumps from one node of Ranvier to the next because the myelin sheath is absent from the nodes. This is known as saltatory conduction, and it allows the nerve impulse to travel much faster along myelinated fibres than along unmyelinated ones.

11 a What is a synapse?

Answer: A synapse is a small gap between one neuron and the next.

b Explain how a nerve message is carried across a synapse.

Answer: At the synapse, neurotransmitter molecules are released from the ends of the axon. They diffuse across the gap and attach to receptors on the membrane of the next neuron.

c Explain why the message can only cross a synapse in one direction.

Answer: The transmission of nerve impulses across a synapse only occurs from axon to dendrite, or from axon to cell body. This is because the receptors for the neurotransmitters only occur on the membranes of the dendrites and on the cell bodies of neurons.

12 What is the difference between a synapse and a neuromuscular junction?

Answer: A synapse is the small gap that occurs between the end branches of an axon of one neuron and a dendrite or the cell body of another neuron. A neuromuscular junction is similar to a synapse; it is a tiny gap between an axon and a skeletal muscle cell.

Apply your knowledge

1 In what ways do nerve cells differ from most body cells?

Answer: Nerve cells have a cell body containing the organelles that most cells have. However, unlike other cells, nerve cells have extensions of cytoplasm. Also, the membrane of nerve cells can be stimulated to generate an action potential, which results in a message being transmitted along the membrane.

2 A nerve impulse is often described as an electrochemical change. Explain why it is described in this way.

Answer: Transmission of a nerve impulse involves the movement of ions across the membrane. It is thus a chemical change. When the ions are exchanged across the membrane, they produce an action potential that involves a change in the membrane voltage. The chemical change therefore produces an electrical change.

3 Hyperkalaemia is a higher than normal level of potassium in the blood and therefore in the extracellular fluid. What effect would hyperkalaemia have on the resting membrane potential of nerve cells?

Answer: The concentration gradient of potassium ions is the most important factor controlling resting membrane potential. If the concentration of potassium in the fluid around a nerve cell is too high, potassium ions cannot be pushed out of the cell and the normal membrane potential cannot be maintained. In extreme cases this would mean that action potentials could not be generated.

4 In an examination a student stated that 'an action potential is another name for a nerve impulse'. Is this statement correct? Explain your answer.

Answer: No, the statement is incorrect. The rapid depolarisation/repolarisation of the membrane is the action potential. Each action potential generates another action potential immediately in front of it, so it is the message (nerve impulse) that travels along a nerve fibre – not the action potential.

5 Lightly press a pencil point onto the skin of your palm. Gradually increase the force with which you are pushing the pencil. How are you able to distinguish different intensities of the same stimulus?

Answer: As you push harder, more receptors are stimulated. These send impulses to the brain. The more impulses, the higher the intensity of the feeling of pain and pressure. The increase in the number of impulses is due to more receptors being stimulated, not the same receptors sending more impulses.

6 The speed of transmission of nerve impulses can vary from 2 m/s to 140 m/s. Explain how there can be such a wide range of speeds of transmission of impulses.

Answer: The speed at which an impulse travels depends on whether the nerve fibre is myelinated or unmyelinated and also on the diameter of the fibre. In unmyelinated fibres the impulse travels steadily along the fibre. The maximum speed of this type of transmission is 2 m/sec.

In myelinated fibres the nerve impulses jump from one gap in the myelin sheath to the next. This jumping conduction allows the nerve impulse to travel much faster than along an unmyelinated fibre. Depending on the diameter of the fibre, impulses can travel at speeds from 18 m/sec up to 140 m/sec.

7 Multiple sclerosis is caused by destruction of the myelin sheath. Use references to find out how damage to the sheath results in the jerky body and limb movements, double vision, slurred speech and paralysis that may occur as a result of the disease.

Answer: The symptoms of multiple sclerosis (MS) are caused by demyelination of nerve cells in the brain and spinal cord. Loss of the myelin sheath results in the nerve cells being unable to communicate effectively with one another. This loss of effective communication between cells in parts of the CNS results in the many and varied symptoms of MS.