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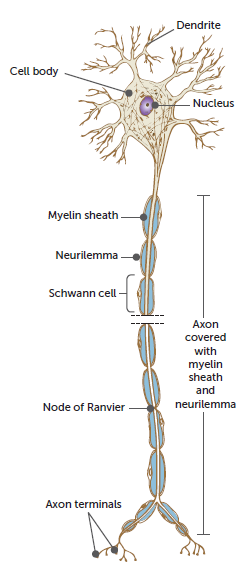
Answers: Chapter 3 Neurons communicate quickly

Questions 3.1

RECALL KNOWLEDGE

**1** Label the diagram below to identify the axon, cell body, myelin sheath, dendrite, nucleus, axon terminal, cytoplasm, node of Ranvier and Schwann cell.

*Answer:* Refer to Figure 3.2 on page 48 of the student book:



**2** Complete the table to state the function of the parts of a neuron.

*Answer:*

|  |  |
| --- | --- |
| **Structure** | **Function** |
| Mitochondria | Site of aerobic respiration and production of ATP. Creating action potentials is an active process and requires ATP. |
| Axon | Transmits the nervous impulse away from the cell body. |
| Dendrite | Transmits the nervous impulse towards the cell body. |
| Myelin sheath | Wraps around the axons to speed up transmission of nerve impulses. |
| Neurilemma | The outermost layer of the Schwann cell to help in the repair of injured cells. |

**3** State the function of:

**a** motor neurons

*Answer:* To carry impulses away from the central nervous system towards an effector.

**b** interneurons

*Answer:* The link the motor and sensory neurons, found in the central nervous system.

**c** sensory neurons.

*Answer:* To carry impulses from receptors in the sense organs towards the central nervous system.

**4** Classify the neuron shown below and justify your choice.

*Answer:* Bipolar neuron. The neuron has one axon and one dendrite with multiple branches occurring off the axon and the dendrite.

**5** Describe the arrangement of nerve fibres in a nerve.

*Answer:* Nerve fibres, when grouped together outside the central nervous system, are called nerves.

**6** Define ‘synapse’ and state its function.

*Answer:* The synapse is the gap at the junction of two adjacent neurons. The synapse allows for the transmission of a nerve impulse from one axon to an adjacent dendrite using neurotransmitters.

APPLY KNOWLEDGE

**7** Explain why the white matter in the brain is white in colour.

*Answer:* The white matter is made up of myelinated fibres. Myelin is a white fatty substance that wraps around the axons of myelinated fibres.

**8** Compare and contrast a synapse and a neuromuscular junction.

*Answer:* Compare: Both the synapse and the neuromuscular junction are gaps that require a neurotransmitter to diffuse across in order to transmit a nervous impulse.

Contrast: A synapse is found between the axon and dendrite of two adjacent neurons. The neuromuscular junction is found at the end of an axon and a skeletal muscle cell.

**9** Suggest why interneurons are multipolar in structure.

*Answer:* An interneuron is designed to integrate activity and connect the sensory and motor neurons in a localised region. The multipolar structure allows for multiple dendrites for sensory neurons to connect to and one axon to deliver the impulse on to a motor neuron. Any other structure would not be as effective at forming the circuits in the central nervous system.

Questions 3.2

RECALL KNOWLEDGE

**1** Describe the difference between an action potential and a nerve impulse.

*Answer:* An action potential is the rapid depolarisation and repolarisation of the membrane, whereas the nerve impulse is the message being carried along the nerve fibre. Another way to look at it is a nerve impulse is multiple and subsequent action potentials.

**2** Are there more sodium leakage channels or potassium leakage channels in the membrane of a neuron?

*Answer:* There are more potassium leakage channels which results in more potassium ions diffusing than sodium ions.

**3** Explain the role of large organic ions in establishing the resting membrane potential.

*Answer:* The large organic ions are negatively charged and are not able to diffuse across the membrane. As such they remain in the cytoplasm and create a more negative environment in the cytoplasm in comparison to the extracellular fluid.

**4** Use a flow chart to describe the events that happen during an action potential.

*Answer:*

**5** Describe the concept of an all-or-none response in relation to an action potential and the relevance of the threshold.

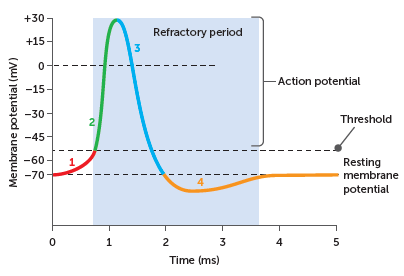
*Answer:* The all-or-none response will occur if the stimulus is strong enough to raise the membrane potential to –55mV. The sodium ions will move into the cell independently of the stimulus and an action potential will be completed. The threshold is the measurement of polarity required for the all-or-none response to occur; this is approximately +15mV from resting membrane potential. If threshold is not met, then an action potential will not occur.

**6** Describe how a nerve impulse travels along a nerve fibre.

*Answer:* The nerve impulse is a series of action potentials. Action potentials occur due to rapid depolarisation and repolarisation of the membrane. This in turn causes local current changes and an action potential in the adjacent membrane. This process occurs along the length of the neuron and is called a nerve impulse.

**7** Draw, and label, a graph representing the membrane potential before, during and after an action potential.

*Answer:* Refer to Figure 3.11 on page 57 of the student book to see an appropriate graph.



**8** List the ways in which a large stimulus is able to be recognised as different from a weak stimulus.

*Answer:* A large stimulus will result in more action potentials being sent along the nerve fibre in a given time. A large stimulus will depolarise more nerve fibres in comparison to a weaker stimulus.

**9** Add labels and additional structures to the diagram below to show how a nerve impulse travels from one neuron to the next.

*Answer:* Refer to Figure 3.14 on page 60 of the student book.

Students should label the arrival of the action potential on the pre-synaptic membrane, the vesicles containing neurotransmitters, the process of exocytosis and diffusion, the receptor proteins and the generation of a new action potential on the post synaptic membrane.

Students need to add voltage-gated calcium channels, Ca2+ ions, a label for the presynaptic neuron and a label for the postsynaptic neuron.

**10** Describe the process of saltatory conduction.

*Answer:* Saltatory conduction is the jumping of action potentials along a myelinated nerve fibre. The myelin sheath acts to insulate the axon from extracellular fluid except at the nodes of Ranvier. As such action potentials jump from one node of Ranvier to the next.

APPLY KNOWLEDGE

**11** Explain the difference between a membrane potential of –70 mV and +40 mV.

*Answer:* This difference is caused by the changing concentrations of sodium ions either side of a membrane during depolarisation. Resting membrane potential is –70mV, some sodium will enter the membrane at stimulus, raising the potential difference to –55mV (threshold). Once threshold is met, sodium channels open and sodium enters the cytoplasm from the extracellular fluid, making the membrane potential rise to +40mV.

**12** Suggest how the resting membrane potential would be different if the sodium–potassium pump did not work.

*Answer:* The sodium-potassium pump works to bring in 2 potassium ions and to move out 3 sodium ions from the cytoplasm. It works to being about a net reduction of positive ions inside the cell and the maintenance of a –70mV resting membrane potential. Without it, as the cell membrane is highly permeable to potassium, more potassium would leave the cytoplasm, making the cytoplasm more negative in relation to the extracellular fluid. The resting membrane potential would be greater than –70mV and it would result in less action potentials being generated as threshold would be met less frequently.

**13** Compare and contrast the progression of a nerve impulse along a myelinated fibre and along an unmyelinated fibre.

*Answer:* Compare: Both fibre types require action potentials to be generated and transmission of the nerve impulse will always be away from the stimulus due to the refractory period.

Contrast: Depolarisation of an unmyelinated fibre causes local current flow and a movement of sodium ions in the adjacent areas. Action potentials are generated along the entire length of the membrane, as such more action potentials occur, and the maximum speed of transmission is 2m/s.

The presence of the myelin sheath insulates the axon from the extracellular fluid. Action potentials are only able to occur at the node of Ranvier as the myelin is not present there. Action potentials will therefore jump from node to node, resulting in saltatory conduction. The maximum speed of transmission is 140m/s.

**14** Explain why organophosphate poisoning results in continual muscle contractions.

*Answer:* Organophosphates cause the build-up of acetylcholine at the neuromuscular junction. As such the skeletal muscle cell is constantly stimulated to contract. The acetylcholine is not able to be broken down or reabsorbed into the presynaptic membrane.

Questions 3.3

RECALL KNOWLEDGE

**1** List the different types of receptors and state the relevant stimulus for each.

*Answer:* Thermoreceptors: Peripheral cold thermoreceptors detect temperatures below 35oC but are most activated at 25 oC. Peripheral hot thermoreceptors detect temperatures above 30 oC but are most activated at 45 oC.

Osmoreceptors: are sensitive to changes in osmotic pressure, or the concentration of substances dissolved in the water of the blood plasma.

Chemoreceptors: stimulated by particular chemicals. Found in the nose for detecting odour, mouth for detecting taste, and internally to detect chemicals in the body fluids.

Touch receptors or mechanoreceptors: Detect light touch, movement of hair follicles, pressure and vibrations.

Pain receptors or nociceptors: detect damage to tissue or excessive stimulation from heat or chemicals.

**2** List the properties of all reflexes.

*Answer:*

• All reflexes require a stimulus

• All reflexes are involuntary

• All reflexes are rapid

• All reflexes are stereotyped

**3** Draw a labelled diagram to represent a spinal reflex arc.

*Answer:* Refer to Figure 3.16 on page 64 of the student book.

APPLY KNOWLEDGE

**4** Compare and contrast pain and touch receptors.

*Answer:* Compare: Both pain and touch receptors can be found in the skin.

Contrast: Touch receptors adapt quickly, meaning that after a period of time we no longer detect the stimulus of touch on our skin (for example clothes touching our skin). Pain receptors do not adapt (or very little), meaning that unless the stimulus is removed the pain receptors will be sending impulses, so the person is aware that a tissue-damaging situation is occurring.

**5** Explain how a gag reflex protects the body.

*Answer:* The gag reflex is triggered by an object touching the top of your mouth, back of the tongue or back of the throat. It will prevent choking and from swallowing potentially hazardous substances.

**6** Describe the steps involved in the reflex initiated by touching a hot object.

*Answer:* Stimulus: Pain receptors and peripheral hot receptors detect the increased temperature.

Sensory neuron: Carries the nerve impulse from the receptor to the spinal cord.

Synapse: There is at least once synapse in the grey matter of the spinal cord, either to an interneuron and then a synapse to a motor neuron, or a direct synapse from sensory neuron to motor neuron.

Motor neuron: Carries the nerve impulse to the effector, in this case the skeletal muscle of the arm.

Effector: The skeletal muscle will contract and pull the hand away from the hot object.

Questions 3.4

RECALL KNOWLEDGE

**1** For each property listed below, state whether it describes the nervous system or the endocrine system.

**a** Has a specific target.

*Answer:* Nervous system

**b** Produces a long-lasting effect.

*Answer:* Endocrine system

**c** Message is carried through the bloodstream.

*Answer:* Endocrine system

**d** Is slow to respond to a stimulus.

*Answer:* Endocrine system

**e** Messages travel due to an electrochemical change.

*Answer:* Nervous system

**f** Affects muscles, glands and other neurons.

*Answer:* Nervous system

**g** Is quick to respond.

*Answer:* Nervous system

**h** Affects all body cells.

*Answer:* Endocrine system

**i** Effects last a short time.

*Answer:* Nervous system

**2** State two ways in which the nervous system is similar to the endocrine system.

*Answer:* Students answers can include two of the following similarities.

• Some substances function as both hormones and neurotransmitters, for example noradrenaline, antidiuretic hormone and dopamine.

• Some hormones, including oxytocin and adrenaline, are secreted by neurons into the extracellular fluid.

• Some hormones and neurotransmitters have the same effect on the same target cells, for example noradrenaline and glucagon both act on liver cells to cause glycogenolysis.

APPLY KNOWLEDGE

**3** Explain why the body needs both the endocrine and nervous systems.

*Answer:* The nervous system and endocrine system compliment and reinforce their respective roles to allow for effective communication within the body. One system alone would not meet the needs for homeostasis or for learning or memory.

**4** Suggest which system (nervous or endocrine) would have the biggest effect on heart rate. Justify your answer.

*Answer:* The nervous system would have the biggest effect on heartrate, as the heart muscle is influenced by the sympathetic and parasympathetic division of the peripheral nervous system. Heartbeat is stimulated by electrical impulses starting at the sinoatrial node (pacemaker of the heart), then to the atrioventricular node, and then to the His-Purkinje network.

Chapter 3 Activities

ACTIVITY 3.1 Creating a model of a neuron

*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 3.2 Storyboarding an action potential

To make your story as accurate as possible, brainstorm the following:

**1** What will be the setting of your story?

**2** What will you (the ion) be doing during each of the different situations?

**3** What other characters will be in your story?

**4** What is the plot of the story?

Write your story using clear explanations. Include relevant scientific terms to ensure the accuracy of the information.

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

* As a sodium ion you spend much of your time in the extracellular fluid around the neuron. There are lots of other sodium ions nearby, plus some chloride ions and a few potassium ions. The neuron looks like a long tube with some while myelin (fatty substance) wrapped around it at equal intervals.
* A stimulus is detected at a receptor nearby and you see that some special sodium-only channels have opened on the surface of the neuron membrane.
* You move through those channels with other sodium ion friends and enter the cytoplasm of the neuron. On the inside now you look around and notice lots of potassium ions, more sodium ions plus some large organic ions in the cytoplasm.
* The environment feels quite a bit more positive than what you experienced outside of the cell. An ion nearby says the membrane is depolarised.
* Not long after you entered, you notice some special potassium-only channels open in the membrane and suddenly heaps of potassium ions are rushing out of the cytoplasm, leaving the space feeling much more negative than before. The same ion states that this is what repolarised feels like.
* You wonder where you are meant to go when you see a sodium-potassium pump and an ATP molecule waiting patiently for you on the membrane.
* You collect two other sodium ion friends and approach the sodium-potassium pump. The pump collects the three of you and pushes you through the membrane back into the extracellular fluid. As you leave the pump you notice two potassium ions being pushed back into the cytoplasm.
* Back in the extracellular fluid you notice the potassium-only channels have closed and the environment is feeling back to the resting potential you experienced before.

ACTIVITY 3.3 Examining the discovery of neurotransmitters

**Questions**

**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 gotten 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). Find out what we now call the neurotransmitter that is 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 include the following:

• 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** 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.

ACTIVITY 3.4 Investigating synapse response in *Daphnia*

Discussion

**1** Evaluate the accuracy of your counting method. Suggest how the accuracy of the procedure might be improved.

*Answer:* Student answers will vary. Students may suggest a greater pool of data, or more rest time for the *Daphnia* between tests. The stress of being contained in the small volume of water can impact the *Daphnia* heart rate.

**2** Describe how each of these chemicals affects the heart rate of the *Daphnia*.

*Answer:* Neurotransmitters transmit nerve impulses from one neuron to another and are responsible for sending signals throughout the body. Without them our hearts would not know to beat, and our lungs would not know to breathe. Alcohol sends the signal to slow the heart rate, while caffeine and nicotine send the message to speed up the heart rate. At low doses, caffeine can slow the heart rate, which is seen in the *Daphnia*, contrary to the general expectation of caffeine.

**3** There are two kinds of neurotransmitters: inhibitory and excitatory. Excitatory neurotransmitters stimulate the brain. Inhibitory neurotransmitters calm the brain and help create balance. Describe how the chemicals you tested affect neurotransmitters in the *Daphnia*.

*Answer:* Caffeine can have an effect on enzymes and hormones in the heart which will in turn have an effect on the heart rate. Nicotine will stimulate the heart rate at low doses via the neurotransmitters norepinephrine and dopamine. At higher doses, it may work via serotonin to slow the heart rate. Alcohol can reduce action potential (electrical impulses) and therefore slow the heart rate.

**4** What factors can cause neurotransmitter levels to become out of balance? Describe how imbalances in neurotransmitter levels may affect human health.

*Answer:* Neurotransmitter levels can be depleted through stress, diet, neurotoxins, drugs, alcohol and caffeine. When out of balance, neurotransmitters can cause issues with focus, sleep, weight management, and more.

ACTIVITY 3.5 Investigating reflexes

**Knee reflex**

**1** Describe the response that occurs. The stimulus for the response is the stretching of the patellar tendon just below the kneecap.

*Answer:* The knee should jerk. That is, the lower limb should kick upwards.

**2** Describe the location of the muscle or muscles that produce the response.

*Answer:* The muscle group that produces the response is the quadriceps. It is located at the front of the thigh and it is the extensor muscle of the knee.

**3** Describe, in words, the reflex arc that is involved in the response. Try to get a response with the knee straight and bent at different angles.

*Answer:* The stimulus is the stretching of the patellar tendon when it is struck below the knee cap. This causes stretch receptors on the tendon to send nerve impulses, via the sensory neuron to the spinal cord. An interneuron transmits the impulse to a motor neuron, which then carries the message to the thigh muscle. The muscle is stimulated to contract, thus causing the knee to extend. (In the patellar reflex the sensory neuron synapses directly with the motor neuron. There is no interneuron, but students could not be expected to know that).

**4** Does the response seem to be stronger at any particular angle of flexion? If so, can you suggest an explanation?

*Answer:* This will vary with the individual, and will probably depend on how much tension there is in the patellar tendon.

**Heel reflex**

**5** Describe the response.

*Answer:* The response is a contraction of the calf muscles, which results in a slight extension (straightening) of the foot. This is known as the ankle jerk reflex or the Achilles reflex.

**6** What is the stimulus in this case?

*Answer:* Stretching of the (Achilles) tendon when struck with a ruler

**7** In what ways is the heel reflex similar to the knee reflex?

*Answer:* In both cases the stimulus is the stretching of a tendon, and the response is contraction of a muscle.

**8** Doctors often test reflexes such as the knee and heel reflex. What do you think testing such reflexes would tell a doctor?

*Answer:* Testing reflexes can determine whether the spinal cord is functioning or damaged at various levels; whether there is normal transmission of impulses along nerve fibres; or whether transmission of impulses at synapses is occurring normally. The tests may also be used to diagnose muscle problems.

**Eye reflex**

**9** Describe any response observed.

*Answer:* Blinking will occur.

**10** Is the response a natural or a learnt response?

*Answer:* Natural

**11** Does the response have a purpose? Explain.

*Answer:* It is a reflex for the protection of the eye against entry of foreign objects.

**Conclusions**

**1** Do all the reflexes that you have investigated have the four important properties that were described in this chapter?

*Answer:* Yes, they should have. They all require a stimulus and are all involuntary, rapid and occur in the same way each time (stereotyped).

**2** Write a brief statement summarising the importance of reflexes to the normal functioning of the human body.

*Answer:* A reflex is a rapid, automatic response to a change in the external or internal environment. Reflexes are one of the ways in which the body achieves homeostasis. Many reflexes are protective, like the blink reflex that protects the eye from foreign objects that may enter the eye, or the reflex that causes a limb to be withdrawn from a painful stimulus.

ACTIVITY 3.6 Investigating reaction time

*Answer:* Responses will depend on the variable being investigated. This activity could form the basis of an open investigation assessment.

Re-reading Chapter 1: Section 1.2 will guide students on identifying the correct variables, ensuring the testing is valid and reliable and reminding them of any ethical considerations they need to undertake prior to conducting any testing. Section 1.2 also covers how to process data and represent it in a meaningful way. Section 1.3 will guide the students on the requirements for each section in a scientific investigation.

ACTIVITY 3.7 Testing more reaction times

**1** Describe the pathway taken by the nerve impulses involved in detecting the stimulus and making the response.

*Answer:* In these online tests the pathway taken by the nerve impulses would be:

Stimulus received at the receptor (the eye); impulses carried by sensory nerve fibres (optic nerve) to cerebrum; impulses transferred to interneuron/s; interneuron carries impulses to motor nerve; motor nerves takes impulses to muscles of hand/arm; impulses causes muscles to contract.

**2** Is the response an innate or an acquired response?

*Answer:* An acquired response

**3** Draw a column graph showing your reaction time for five trials.

*Answer:* Student answers will vary. The five trials will be on the x axis and reaction time will be on the y axis.

**4** Does your reaction time decrease with practice? If so, suggest why.

*Answer:* Most subjects find that they improve with practice. This could be because of:

• increased familiarity with the stimulus

• learning to respond to the stimulus

• establishing a pathway for the nerve impulses to travel.

**5** Do five trials with your left hand and then five trials with your right hand. Describe and explain any difference between the two sets of trials.

*Answer:* For a simple response like clicking a mouse or striking a key on the computer keyboard there is likely to be little difference between the two hands.

For responses requiring more motor coordination the dominant hand is likely to be faster.

CHAPTER 3 REVIEW QUESTIONS

Recall

**1** 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.

**2** One way that neurons can be classified is based on their function. Name the three types of neurons and describe the function of each.

*Answer:*

|  |  |
| --- | --- |
| **Neuron type** | **Function** |
| Sensory | To carry nerve impulses from a receptor in towards the central nervous systems (brain and spinal cord) |
| Connector | To connect the sensory and motor neurons, to relay messages within the central nervous system |
| Motor | To carry nerve impulses away from the central nervous system towards an effector to produce a desired response. |

**3 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.

**4 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.

**5** 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.

**6 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.

**7 a** What is a synapse?

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

**b** Describe 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.

**8** 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.

**9 a** Describe three differences between the action of nerves and that of hormones.

*Answer:* Differences between the action of nerves and hormones include the following:

• Nervous responses are usually more rapid than hormonal ones, because nerve impulses travel rapidly along nerve fibres, while hormones are transported in the bloodstream.

• Nerve impulses bring about an immediate response, which lasts for only a short time. Hormones are typically slower acting, and responses can last a considerable time, even years.

• Nervous messages are an electrochemical change that travels along the membrane of a neuron. Endocrine messages are hormones, chemical substances that are usually transported by the blood.

• Nerve impulses travel along a nerve fibre to a specific part of the body, and often influence just one effector. Hormones travel to all parts of the body, carried by the blood, and often affect a number of different organs.

**b** Describe some of the similarities between the nervous and endocrine systems.

*Answer:*

• Substances such as noradrenaline, antidiuretic hormone and dopamine function as both hormones and as neurotransmitters.

• Neurons secrete some hormones, such as oxytocin and adrenaline.

• Some hormones and neurotransmitters have the same effect on the same target cells. For example, noradrenaline and the hormone glucagon both act on liver cells to cause glycogen to be broken down to glucose.

**10** In what parts of the body are thermoreceptors found?

*Answer:* Thermoreceptors are found in:

• the skin where they detect changes in the environmental temperature

• the hypothalamus where they detect the temperature of the blood flowing through the brain.

**11** In the diagram below, identify the receptors that would be stimulated by:

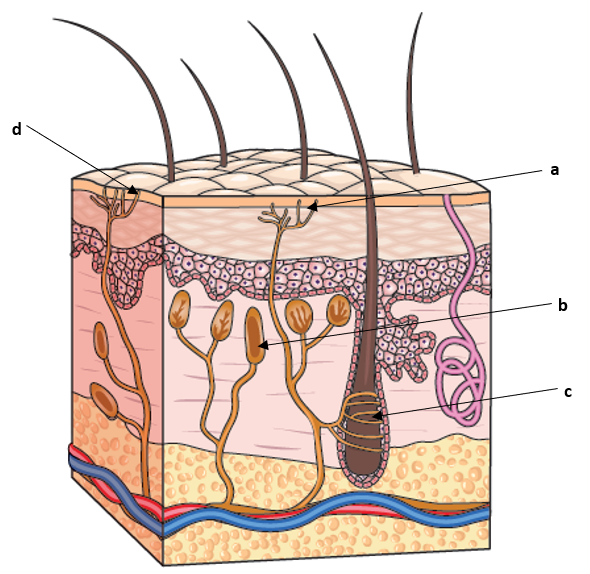
**a** light touch

**b** pressure or vibration

**c** movement of hairs

**d** pain.

*Answer:*



Explain

**12** 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.

**13 a** Explain the difference between multipolar, bipolar, unipolar and pseudounipolar neurons.

*Answer:* Multipolar neurons have one axon and many dendrites extending from the cell body.

Bipolar neurons have one axon and one dendrite, each of which may have many branches at their ends.

Unipolar neurons have only one extension, an axon with the cell body located to one side of the axon.

Pseudounipolar neurons have properties of both unipolar and bipolar neurons. There is a single axon from the cell body which then separates into two extensions. One extension connects to dendrites while the other ends in axon terminals. The cell body lies to one side of the main axon.

**b** Give an example of where each of these can be found.

*Answer:* Multipolar neurons can be found as most of the interneurons in the brain and spinal cord and also the motor neurons that carry messages to the skeletal muscles.

Bipolar neurons can be found in the eye, ear and nose, where they transfer impulses from the receptor cells to other neurons.

Unipolar neurons are found as sensory neurons that carry messages to the spinal cord, but cannot be found in humans or vertebrates, they are only found in insects.

Pseudounipolar neurons are sensory neurons that carry messages to the spinal cord.

**14** 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.

**15** 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.

**16** Explain the role of calcium ions in the transmission of a nerve impulse across a synapse.

*Answer:* When an action potential reaches the axon terminal, voltage-gated calcium ion channels open. Calcium ions enter the presynaptic axon terminal and this causes the vesicles to fuse to the membrane and to release the neurotransmitters inside via exocytosis. The diffusion of the neurotransmitters across the synapse starts a new action potential on the postsynaptic neuron.

**17** Explain why a nerve impulse 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.

**18** Explain how we are able to distinguish between a light touch and heavy pressure on the skin.

*Answer:* We are able to differentiate between these two stimuli because they are detected by different receptors. A light touch stimulates touch receptors that are close to the surface of the skin and send messages to the brain so that we become aware of the light touch. Heavy pressure stimulates receptors much deeper in the skin and these make us consciously aware of the heavy pressure.

Apply

**19** 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.

**20** 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.

**21** 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.

**22** 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.

**23** Lightly press a pencil point on to 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.

**24** 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.

**25** Name the type of receptor that would recognise:

**a** an increase in carbon dioxide in the blood

*Answer:* Chemoreceptor

**b** a graze on an elbow

*Answer:* Nociceptor (pain receptor)

**c** a light breeze blowing.

*Answer:* Mechanoreceptor (touch receptor)

**26** Many reflexes are protective. List five protective reflexes.

*Answer:* Protective reflexes include:

• blinking to protect the eye

• sneezing to remove irritants from the nasal cavity

• coughing to remove particles from the respiratory tract

• vomiting to remove irritating substances from the stomach

• constriction of the pupil to protect the retina from bright light

• withdrawal of a limb from a painful stimulus

• closing of the epiglottis when swallowing to prevent food and drink entering the trachea.

Students may be able to think of other valid examples.

**27** A driver approaching traffic lights saw the lights change from green to amber. She transferred her foot from the accelerator to the brake in order to stop. Describe the pathways of the nerve impulses that would be involved in this response.

*Answer:* The photoreceptors in the eye (retina) send impulses to the sensory area of the cerebral cortex. The driver has learned that amber means prepare to stop so impulses are then sent to the motor area of the cortex. The motor area sends impulses through motor neurons to the muscles of the leg and foot. When the impulses reach the muscles they cause contraction, so that the foot is moved from the accelerator to the brake.

**28** When you withdraw your hand from a painful stimulus, the response occurs before you become consciously aware that you have hurt yourself. Explain how this is possible.

*Answer:* Withdrawing the hand from a painful stimulus is a reflex action. The response would be coordinated by the spinal cord. When the nerve impulses enter the spinal cord from pain receptors in the hand, they are passed to motor neurons at the same level in the cord. The motor neurons carry the impulses to the arm muscles causing contraction and withdrawal of the hand.

At the same time messages are transmitted to the brain so that the person will become consciously aware of what is happening. However, the pathways to the brain involve many more synapses than those of the simple reflex, so that transmission of impulses is much slower. Thus the response may have actually occurred just before the person becomes consciously aware of it.

**29** Why would it be unwise to continually take painkillers for a particular pain without seeking medical help?

*Answer:* Pain is an indication that tissues are being damaged. If the pain is continually masked by pain killers serious damage to tissues could be occurring.

Extend

**30** 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.

**31** Doctors may use reflexes to find out whether a patient has an impairment of the nervous system. Absence or exaggeration of a particular reflex may indicate damage to nerves or to the spinal cord through injury or disease.

Conduct research to find out about the following reflexes and what absence or exaggeration of the reflex could indicate:

**a** patellar reflex (knee jerk)

**b** Achilles reflex (ankle jerk)

**c** abdominal reflex

**d** plantar reflex and Babinski sign.

*Answer:*

|  |  |  |
| --- | --- | --- |
| **Reflex type** | **Description** | **Absence or exaggeration indicator** |
| Patella reflex | Striking the patella tendon with a reflex hammer just below the patella stretches the muscle spindle in the quadriceps muscle. This causes the quadriceps muscles to contract and the lower leg will kick. It is used to test the lumbar (L) 2, L3 and L4 segments of the spinal cord. | Absence or decrease of the reflex is known as Westphal’s sign and may be due to lower motor neuron lesions.  Exaggerated responses are a result of upper motor neuron lesions, hyperthyroidism anxiety or nervousness. |
| Achilles reflex | The ankle jerk reflex occurs when the Achilles tendon is tapped when the foot is dorsiflexed. It is used to test the gastrocnemius muscle and the nerve that supplies it. | Absence of the reflex could be indicative of sciatic nerve pathology. It is classically delayed in hypothyroidism.  It is absent in disk herniations at the L5 – S1 level. |
| Abdominal reflex | The abdominal reflex is a superficial neurological reflex stimulated by stroking of the abdomen around the umbilicus (navel). | Absences could be attributed to a physiological reason including obesity, tolerance, multiparous lax abdominal wall.  Pathological absence can be due to multiple sclerosis, late motor neuron disease, neurogenic bladder, Brown-Sequard syndrome, Chiari malformation. |
| Plantar reflex and Babinski sign | The plantar reflex is elicited when the sole of the foot is stimulated with a blunt object. It results in two forms, the downward response/flexion of the hallux (big toe) or an upward response/extension of the hallux. | The Babinski response/sign is when the hallux extends. It is an indicator of disease of the spinal cord and brain in adults. It is also a primitive reflex in infants which is normal and is lost as the infant develops. |