15. Control and Coordination

15.1 Control and Coordination in Mammals

Paper 4

Question Paper

1 **(a)** Fig. 8.1 is a diagram of a sensory neurone.

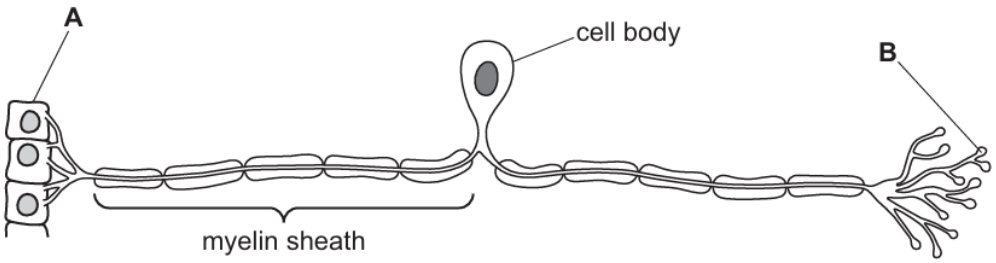


Fig. 8.1

(i) Name the type of cell represented by cell **A**.

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(ii) Name a type of cell that forms a synapse with structure **B**.

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(iii) Name the cells that form the myelin sheath.

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(b) State **and** explain the differences in the transmission of impulses between myelinated and unmyelinated neurones.

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(c) Opioids are therapeutic drugs that are used to relieve pain. Morphine is an example of an opioid. It affects the functioning of synapses.

Fig. 8.2 is a diagram of a cholinergic synapse.

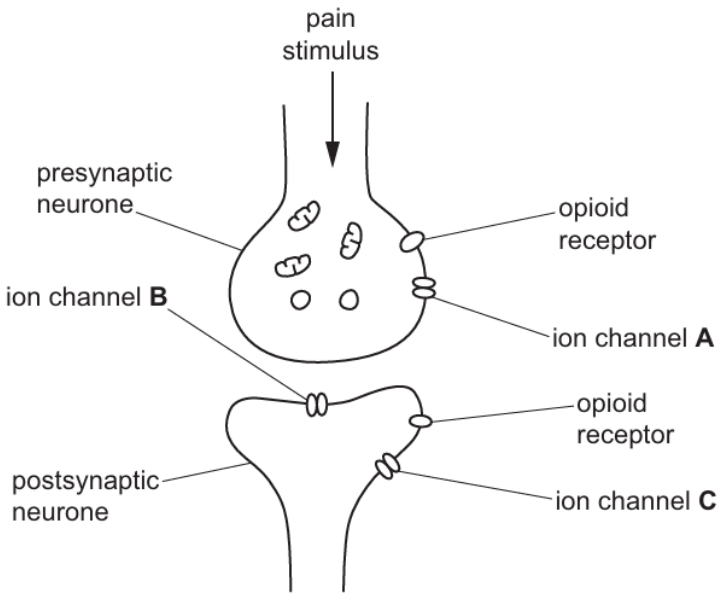


Fig. 8.2

(i) With reference to Fig. 8.2, describe the differences between ion channel **A** and ion channel **B**.

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(ii) Morphine binds to the opioid receptor in the presynaptic membrane. This stops the ion channel **A** from opening.

Suggest **and** describe the effects of the binding of morphine to this opioid receptor on the functioning of the cholinergic synapse.

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(iii) Morphine also binds to the opioid receptor in the postsynaptic membrane. This results in the opening of ion channel **C**, allowing potassium ions to diffuse out of the cell.

Suggest how this would affect the synapse.

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2 **(a)** Coordination in humans involves two main systems: the nervous system and the endocrine system. Paracrine cell signalling is a third way in which coordination occurs. In paracrine signalling, one cell secretes a chemical that diffuses a short distance to act upon cells that are very near to the secreting cell.

(i) Identify **one** similarity and **one** difference between paracrine cell signalling and cell signalling that occurs as part of the endocrine system.

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(ii) Explain why a neurotransmitter such as acetylcholine could be described as a paracrine signalling molecule.

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(b) Human muscle cells show paracrine signalling. After muscle cells have been exposed to a substance called palmitate they:

- produce a signalling molecule
- show an increase in the expression of genes involved in a stress response (stress genes).

Scientists carried out three experiments to investigate the signalling molecule produced by muscle cells after they have been exposed to palmitate.

Experiment A

- Muscle cells were exposed to palmitate.
- The palmitate-exposed muscle cells were removed from the medium containing palmitate and then cultured in a nutrient medium for six days.
- The palmitate-exposed cells were removed from the nutrient medium and **new** muscle cells were placed in this used nutrient medium.
- The expression of stress genes in the **new** muscle cells was measured after 24 hours.
- A **control** using cells that had **not** been exposed to palmitate was also carried out.

Experiment B

Experiment **A** was repeated but the used nutrient medium for the palmitate-exposed cells and the control was boiled and then cooled before adding the new muscle cells.

Experiment C

Experiment **A** was repeated but the used nutrient medium from the palmitate-exposed cells and the control was treated to separate the lipid part. This lipid part was added to a new nutrient medium to culture the new muscle cells.

The results are shown in Fig. 2.1.

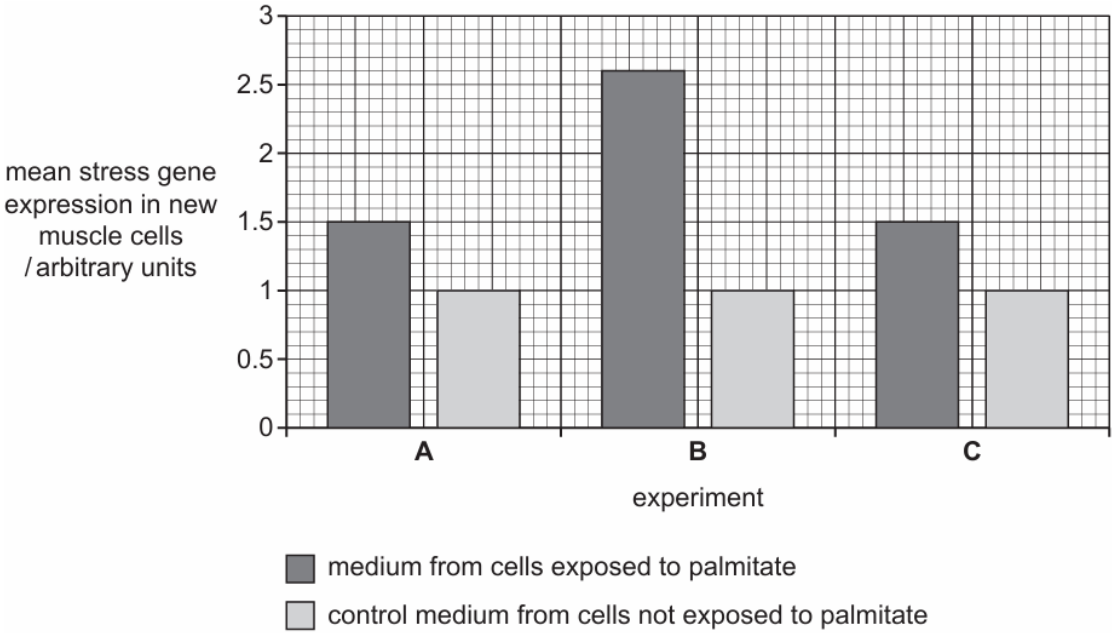


Fig. 2.1

With reference to Fig. 2.1, outline the conclusions that can be drawn about the cell signalling molecule involved in human muscle cell paracrine signalling in response to palmitate.

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(c) The process of protein translation is inhibited in developing muscle cells when stress genes are expressed.

Suggest how developing muscle cells that express stress genes will differ in structure from normal muscle cells.

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3 Humans detect the sweet taste of sucrose sugar using chemoreceptor cells in taste buds on the tongue. The red admiral butterfly, *Vanessa atalanta*, detects sucrose using chemoreceptor cells located on its antennae and on its tarsi (feet). The mode of action of the chemoreceptors in *V. atalanta* is similar to that in humans.

Fig. 10.1 shows the locations of the chemoreceptor cells on *V. atalanta.*



Fig. 10.1

Describe how the presence of sucrose causes an action potential in the sensory neurone associated with a chemoreceptor cell in *V. atalanta*.

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4 **(a)** Fig. 8.1 is a diagram of a motor neurone.

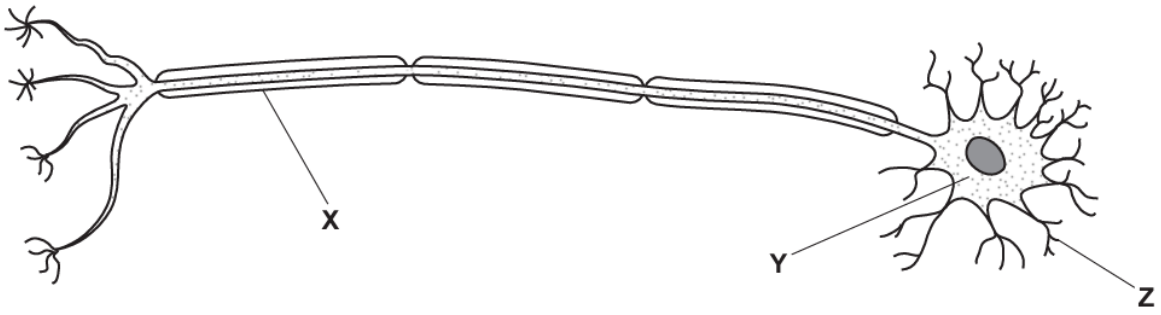


Fig. 8.1

(i) Name cell **X** and part **Y**.

X .....

Y .....

[2]

(ii) Name a type of cell that forms a synapse with structure **Z**.

..... [1]

(b) Table 8.1 shows some of the events that occur during muscle contraction.

They are **not** listed in the correct order.

Table 8.1

event	description of event
A	calcium ions diffuse out of sarcoplasmic reticulum
B	myosin heads bind to actin
C	sarcolemma depolarised
D	sarcomere shortens
E	calcium ions bind to troponin
F	T-tubule system membranes depolarised
G	binding sites on actin exposed
H	myosin heads tilt
I	tropomyosin moves
J	troponin changes shape

Complete Table 8.2 to show the correct order of the events that occur during muscle contraction. Two of the events have been completed for you.

Table 8.2

correct order	letter of event
1	.....
2	.....
3	.....
4	.....
5	**J**
6	.....
7	.....
8	.....
9	.....
10	**D**

[4]

(c) Lambert-Eaton myasthenic syndrome (LEMS) is a rare disorder of the neuromuscular junction. A person with LEMS produces antibodies that bind to the voltage-gated calcium channels on the presynaptic knob. One symptom of LEMS is weaker muscle contraction.

Suggest **and** explain why LEMS leads to weaker muscle contraction.

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5 Different species of animal have neurones with different characteristics.

(a) Fig. 1.1 is a diagram of a motor neurone of a rat and a motor neurone of a snail.

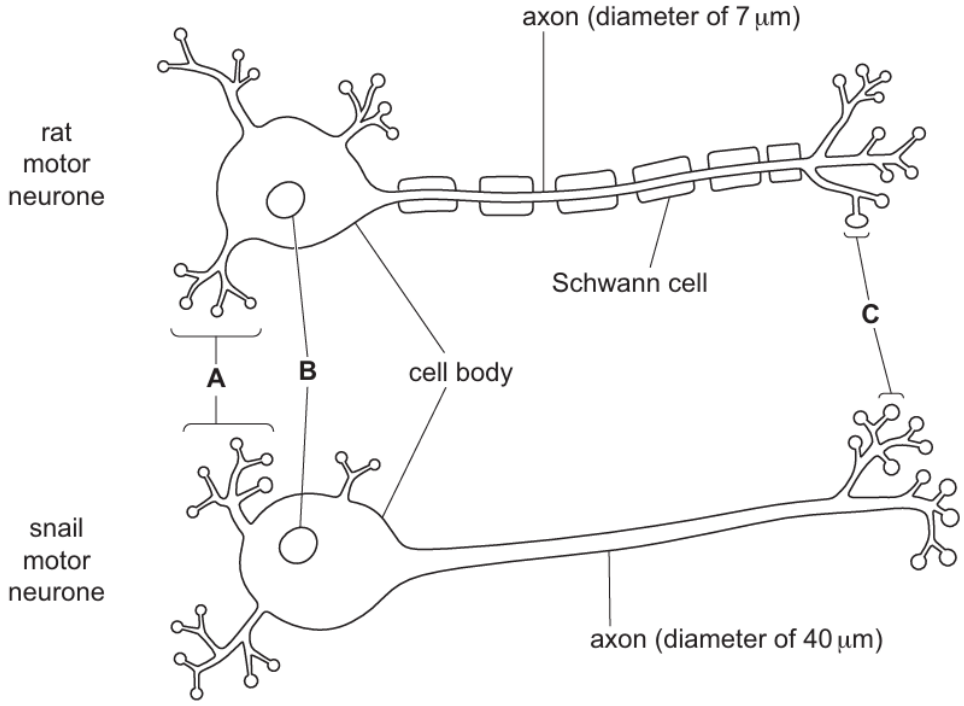


Fig. 1.1

(i) Name the structures labelled **A**, **B** and **C** on Fig. 1.1.

A .....

B .....

C .....

[3]

(ii) The rat motor neurone has an impulse transmission speed of $50\,m\,s^{-1}$. The snail motor neurone has an impulse transmission speed of $8\,m\,s^{-1}$.

Explain why the rat motor neurone has a faster impulse transmission speed than the snail motor neurone.

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(b) Fig. 1.2 shows an action potential in a rat neurone and Fig. 1.3 shows an action potential in a snail neurone.

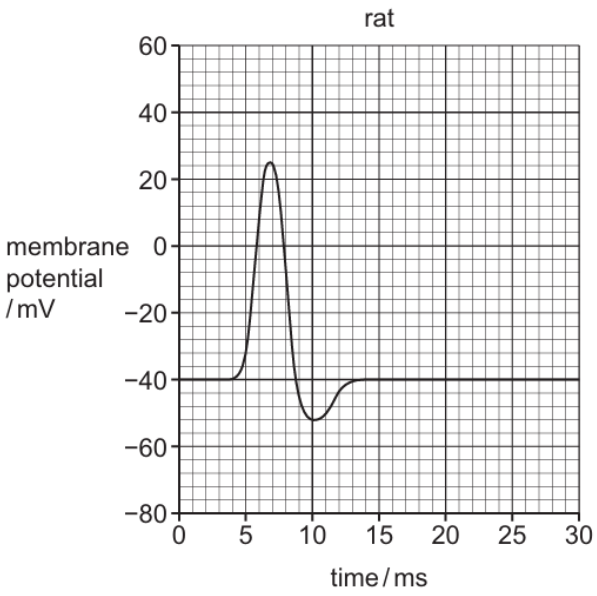


Fig. 1.2

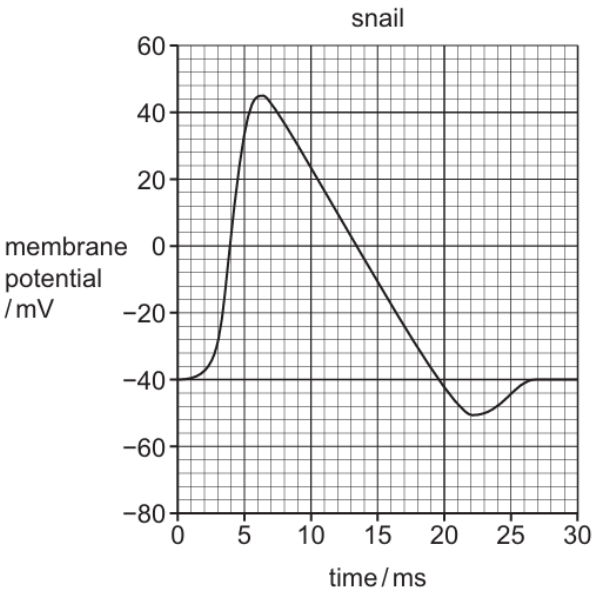


Fig. 1.3

Contrast the two action potentials shown in Fig. 1.2 and Fig. 1.3.

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6 **(a)** A striated muscle cell (muscle fibre) will contract when stimulated by a motor neurone at a neuromuscular junction.

Air temperature can affect the temperature of striated muscle cells.

Investigations have shown that the efficiency of contraction of striated muscle cells decreases when the air temperature decreases.

Suggest reasons why a reduction in temperature can decrease the efficiency of contraction of striated muscle cells.

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..... [4]

(b) The greater blue-ringed octopus, *Hapalochlaena lunulata*, produces tetrodotoxin (TTX). TTX is a neurotoxin. If a mammal is bitten by this octopus, the effect of TTX can cause the death of the mammal.

Fig. 7.1 shows a greater blue-ringed octopus.

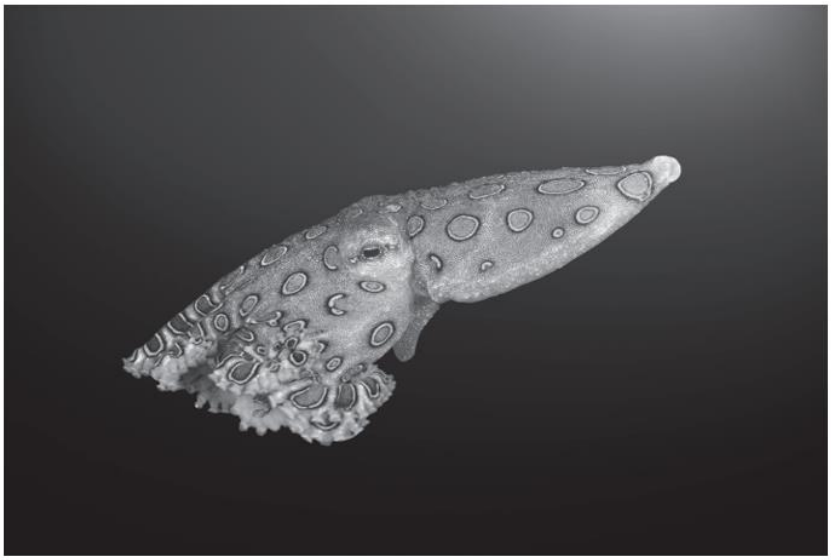


Fig. 7.1

TTX binds to voltage-gated sodium ion channels in the axon of a neurone and changes the tertiary structure of the channel protein.

Suggest how TTX may affect the functioning of a motor neurone.

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7 Amino acids are the monomers that are used to produce proteins in organisms. Amino acids also have other, non-protein, roles in the body.

(b) The amino acid glycine can act as a neurotransmitter.

A glycinergic synapse is shown in Fig. 7.2.

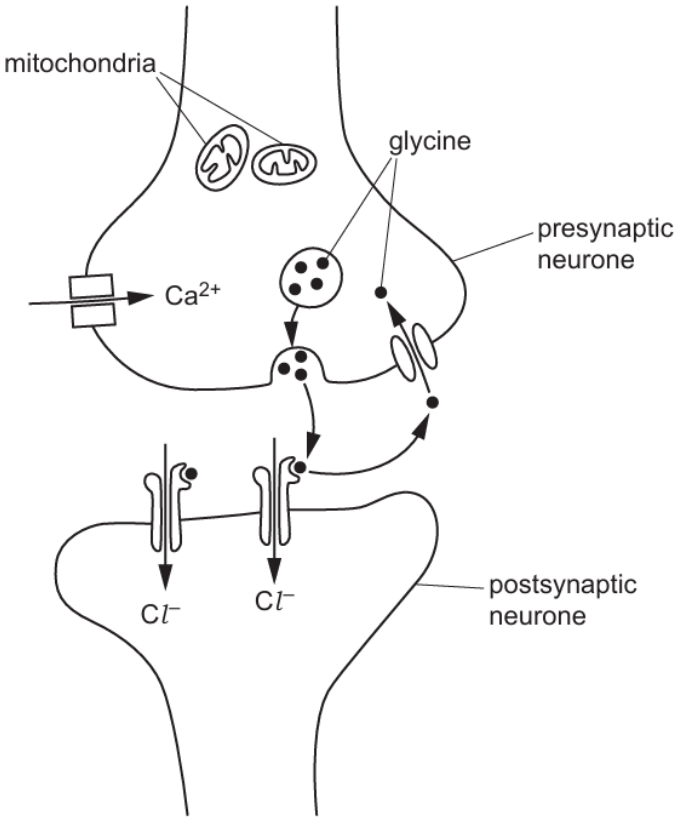


Fig. 7.2

(i) The glycinergic synapse and a cholinergic synapse use different neurotransmitters and different postsynaptic receptors.

Describe differences between the glycinergic synapse shown in Fig. 7.2 and a cholinergic synapse.

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(ii) The binding of glycine to receptors, as shown in Fig. 7.2, makes an action potential less likely to occur in the postsynaptic neurone.

Suggest why an action potential is less likely to occur after the binding of glycine to receptors.

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(iii) Neurones need to maintain a resting potential before an action potential can occur.

Describe how a neurone maintains a resting potential.

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8 **(a)** There are many mitochondria located in the presynaptic knobs of neuromuscular junctions and in the sarcomeres of muscle fibres of striated muscle.

Explain the need for many mitochondria in the presynaptic knobs and in the sarcomeres.

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(b) Fig. 7.1 is a diagram of synapses between a postsynaptic neurone and two presynaptic neurones, **X** and **Y**.

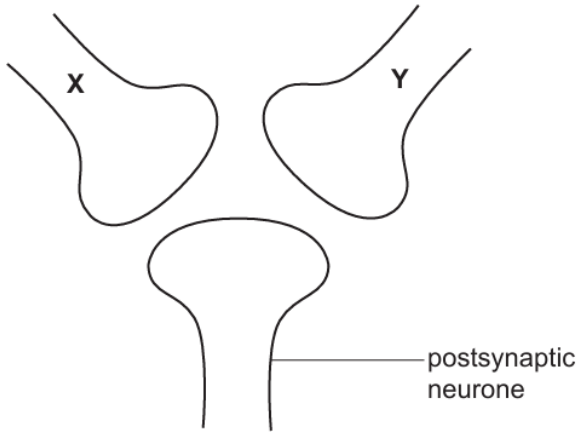


Fig. 7.1

- Neurone **X** releases the neurotransmitter acetylcholine.
- Neurone **Y** releases the neurotransmitter glutamate.
- Both neurotransmitters bind to channel proteins in the membrane of the postsynaptic neurone.
- Acetylcholine binding results in an influx (entry) of sodium ions.
- Glutamate binding results in an influx of chloride ions.

A student made three statements:

1. When only neurone **X** is stimulated, an action potential **will** occur in the postsynaptic neurone.
2. When only neurone **Y** is stimulated, an action potential **will** occur in the postsynaptic neurone.
3. When neurone **X** and neurone **Y** are stimulated at the same time, an action potential **will not** occur in the postsynaptic neurone.

Explain whether or not you agree with these statements.

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(c) Multiple sclerosis is a condition in which the myelin sheath breaks down in some neurones.

Suggest the effect of multiple sclerosis on the transmission of action potentials in the affected neurones.

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9 **(b)** Outline the differences between the endocrine system and the nervous system.

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10 When an impulse arrives at a neuromuscular junction, it stimulates a muscle fibre of striated muscle to contract.

(a) (i) Outline the **similarities** in structure between a neuromuscular junction and a cholinergic synapse.

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..... [4]

(ii) The hydrolysis of ATP during muscle contraction releases inorganic phosphate (P_i).

Calcium ions (Ca^{2+}) can combine with P_i in the sarcoplasmic reticulum to form insoluble calcium phosphate. This may result in fewer power strokes occurring in sarcomeres.

Suggest why calcium phosphate formation in the sarcoplasmic reticulum may result in fewer power strokes occurring in sarcomeres.

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11 Green lacewings are a family of insects with more than 1300 species.

The common green lacewing, *Chrysoperla carnea*, is shown in Fig. 9.1.

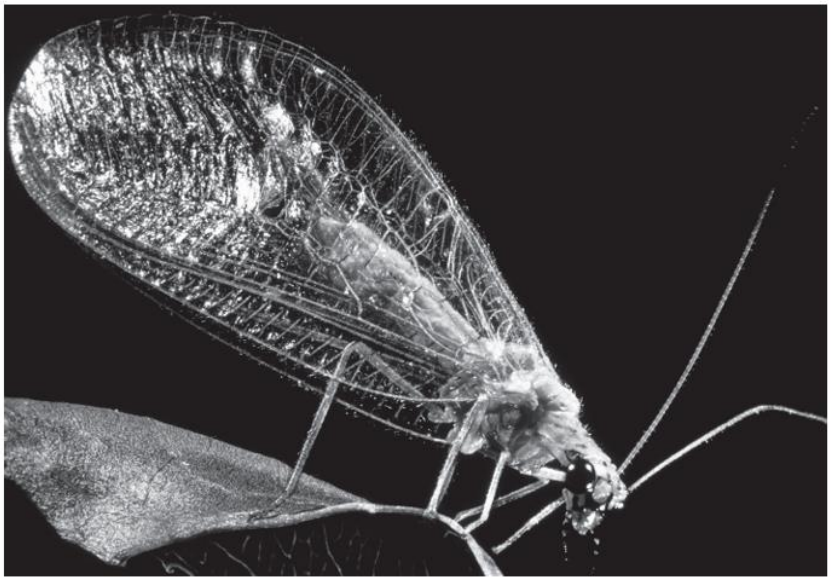


Fig. 9.1

(a) Green lacewings have sense organs, known as tympanal organs, that detect sound.

The tympanal organ of green lacewings has evolved to detect the high frequency sounds that bats make when they are hunting. Bats eat green lacewings.

When a green lacewing senses the presence of a bat, it moves away or closes its wings in flight to escape.

(ii) When high frequency sound is detected, the receptor cells in the tympanal organ stimulate the transmission of impulses in sensory neurones.

Describe the sequence of events that results in an action potential in a sensory neurone.

The first event in the sequence has been given for you.

Calcium ions enter the cytoplasm of the receptor cell .....

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..... [4]

12 **(a)** A neuromuscular junction allows the transmission of an action potential from a motor neurone to a striated muscle fibre, causing it to contract.

Fig. 9.1 is a graph of an action potential in a motor neurone.

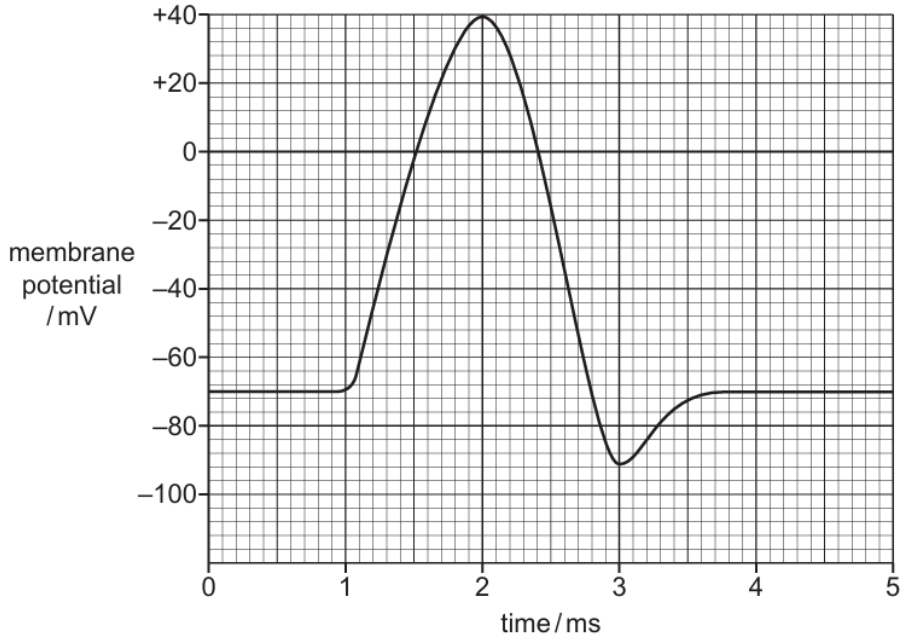


Fig. 9.1

Fig. 9.2 is a graph of an action potential in a striated muscle fibre.

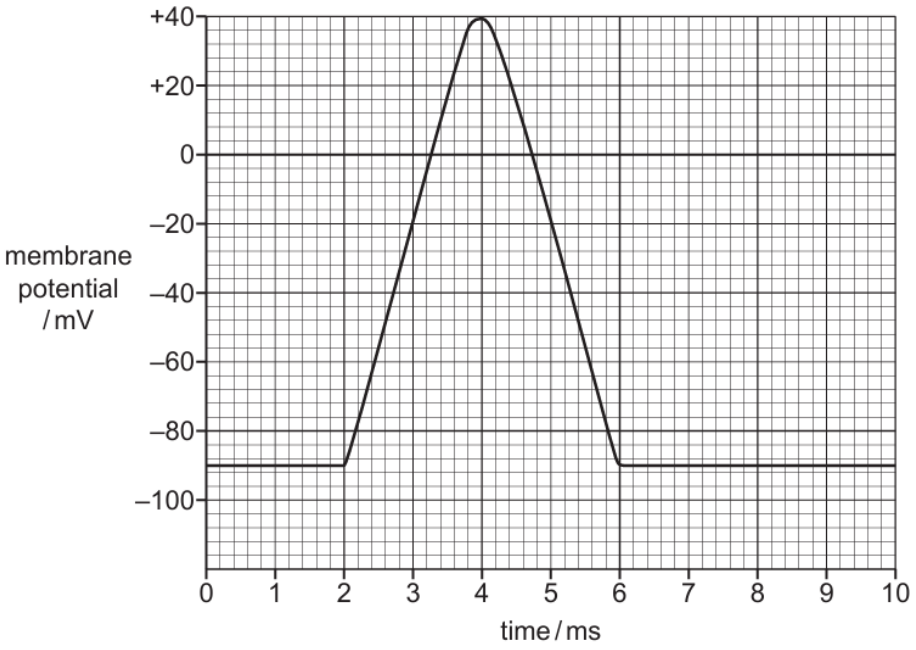


Fig. 9.2

With reference to Fig. 9.1 and Fig. 9.2, describe the differences between the action potential in a motor neurone and the action potential in a striated muscle fibre.

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(b) There are three phases in the contraction of a striated muscle: latent phase, contraction phase and relaxation phase.

The tension in a muscle represents the degree of contraction of its fibres.

Fig. 9.3 is a graph of the tension in a striated muscle during the three phases of contraction.

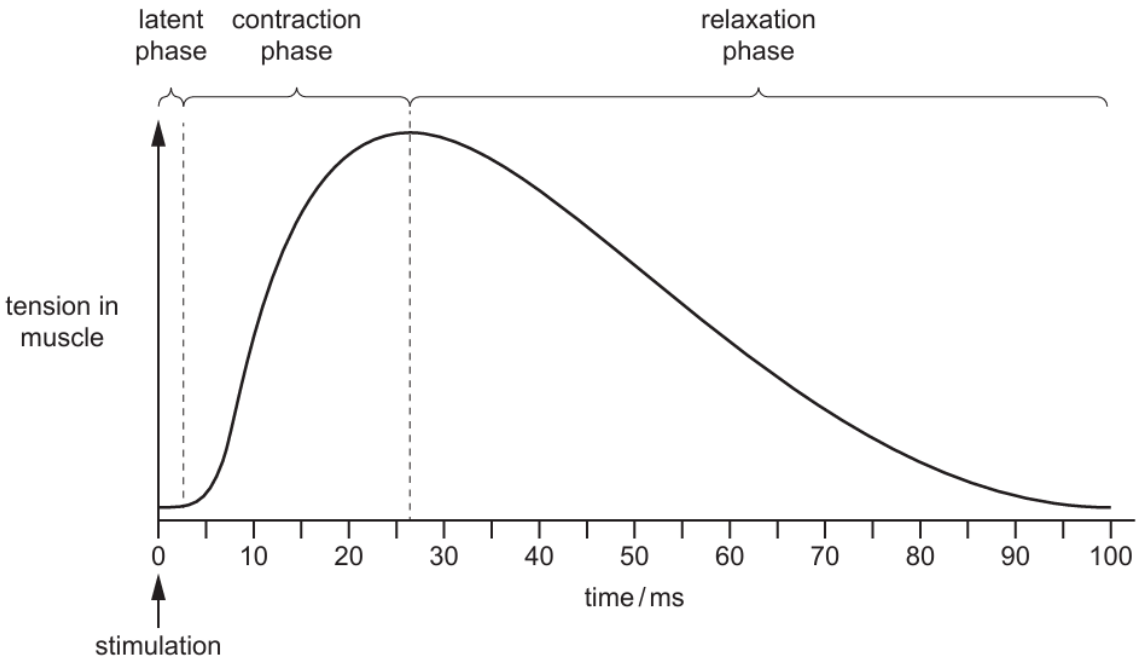


Fig. 9.3

(i) With reference to Fig. 9.3, explain what is happening in the striated muscle fibre during the latent phase.

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(ii) Suggest why the relaxation phase shows a gradual decrease in muscle tension.

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13 **(b)** The toxin in the skin of the golden mantella affects the action of the sarcomeres in muscle fibres (muscle cells) of mammalian striated muscle. The toxin inhibits a protein, Ca^{2+}ATPase, found in the membrane of the sarcoplasmic reticulum.

Ca^{2+}ATPase pumps calcium ions from the cytoplasm into the sarcoplasmic reticulum when the fibre is no longer stimulated.

Suggest the consequences to the sarcomere of the action of the golden mantella toxin.

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(c) Describe the role of calcium ions in a cholinergic synapse.

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14 **(a)** Motor neurones and sensory neurones have different roles in nervous coordination.

Contrast the structure **and** function of sensory neurones and motor neurones.

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(b) Mammals have many types of neurones, which vary in axon diameter and myelination.

Table 10.1 shows the axon diameter and mean impulse transmission speed of four different types of mammalian neurone.

Table 10.1

neurone type	myelination	mean axon diameter /μm	mean impulse transmission speed / m s^{-1}
motor α	✓	13.0–20.0	80–120
motor β	✓	6.0–12.0	35–75
motor δ	✓	1.0–5.0	5–35
motor C	✗	0.2–1.5	0.5–2.0

Using the data shown in Table 10.1, comment on the relationship between:

- myelination and mean impulse transmission speed
- axon diameter and mean impulse transmission speed.

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(c) Fig. 10.1 is a graph of an action potential in a mammalian neurone.

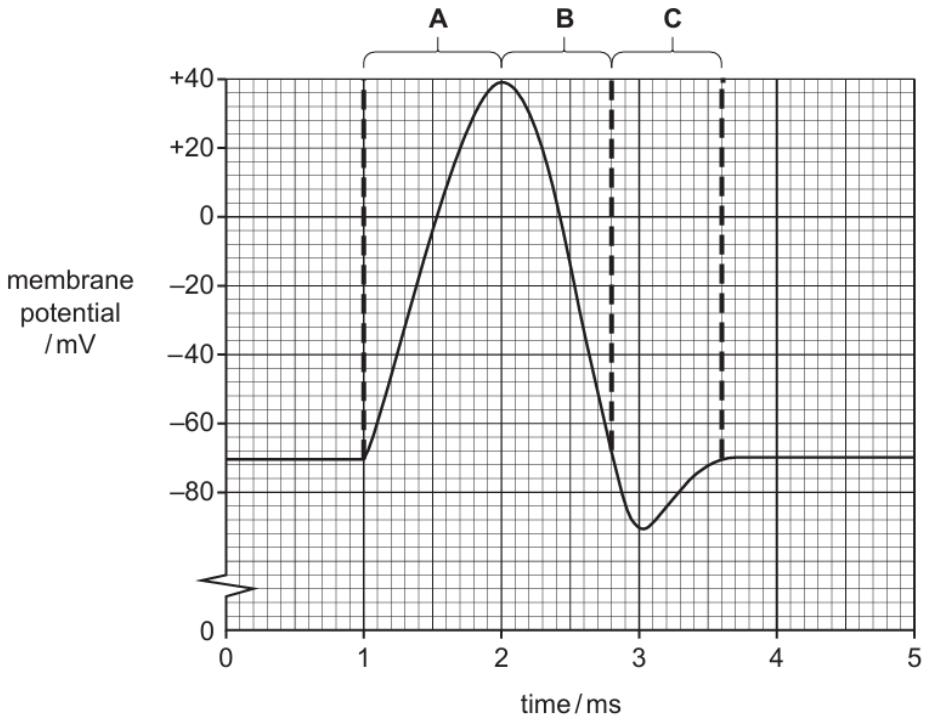


Fig. 10.1

With reference to Fig. 10.1 suggest why:

- no further action potential can occur during **A** and **B**
- it is difficult for a further action potential to occur during **C**.

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..... [3]

15 The role of sensory receptor cells in mammals is to detect stimuli and generate action potentials in sensory neurones.

Human taste buds on the tongue contain chemoreceptor cells. Different chemoreceptor cells respond to different chemical stimuli.

Fig. 8.1 is a diagram of chemoreceptor cells in a taste bud.

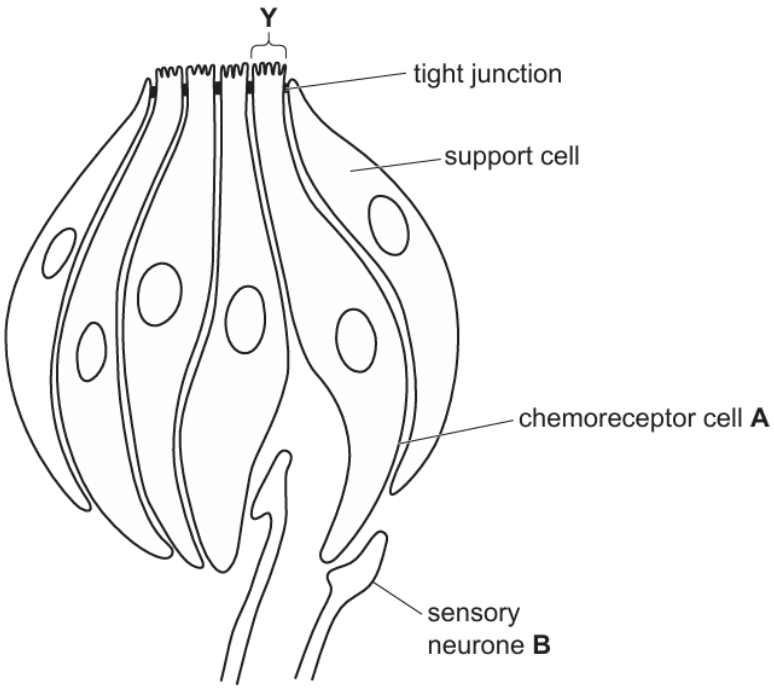


Fig. 8.1

(a) Name the structures in the region **Y**.

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(b) Suggest a reason for the tight junctions between the chemoreceptor cells.

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(c) Chemoreceptor cell **A** responds to sodium ions (Na^+) in salt.

Describe how the contact of cell **A** with Na^+ can result in an action potential in sensory neurone **B**.

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16 **(a)** Fig. 1.1 is a diagram of part of a neurone membrane at resting potential.

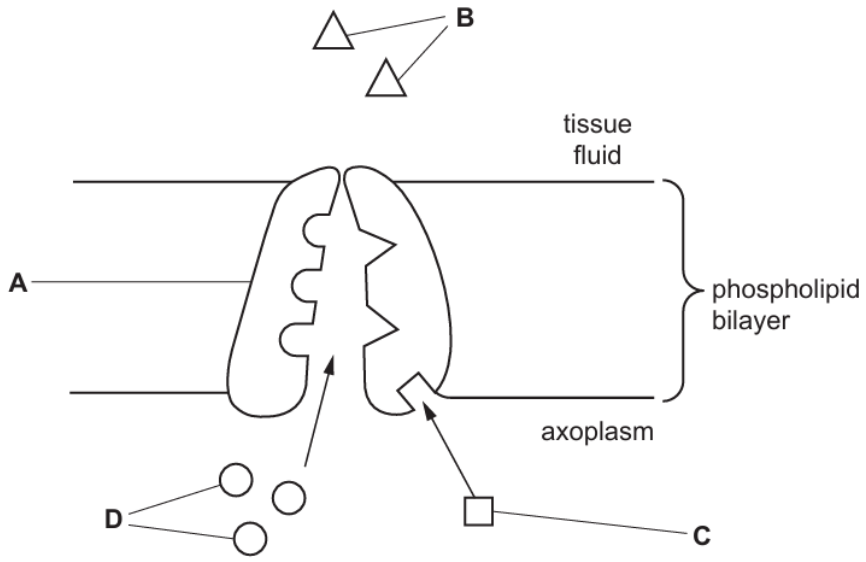


Fig. 1.1

(i) With reference to Fig. 1.1, name **A**, **B**, and **D**.

A .....

B .....

D ..... [3]

(ii) Substance **C** is required to make structure **A** function.

Name substance **C**.

..... [1]

(b) Some drugs can affect the functioning of neuromuscular junctions or cholinergic synapses.

Table 1.1 lists three drugs and describes their action on neuromuscular junctions or cholinergic synapses.

Table 1.1

drug	action of drug
curare	blocks muscle cell membrane receptors at neuromuscular junctions
nerve gas	inhibits acetylcholinesterase function in synapses
alcohol	inhibits exocytosis of neurotransmitters in synapses

Suggest **and** describe the immediate consequence of the action of each drug on a neuromuscular junction or cholinergic synapse.

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17 Glucagon-like peptide-1 (GLP-1) is a hormone consisting of 31 amino acids. It is secreted by specialised intestinal epithelial cells known as L cells.

Fig. 6.1 outlines the secretion of GLP-1 and its effects on the pancreas, brain and stomach.

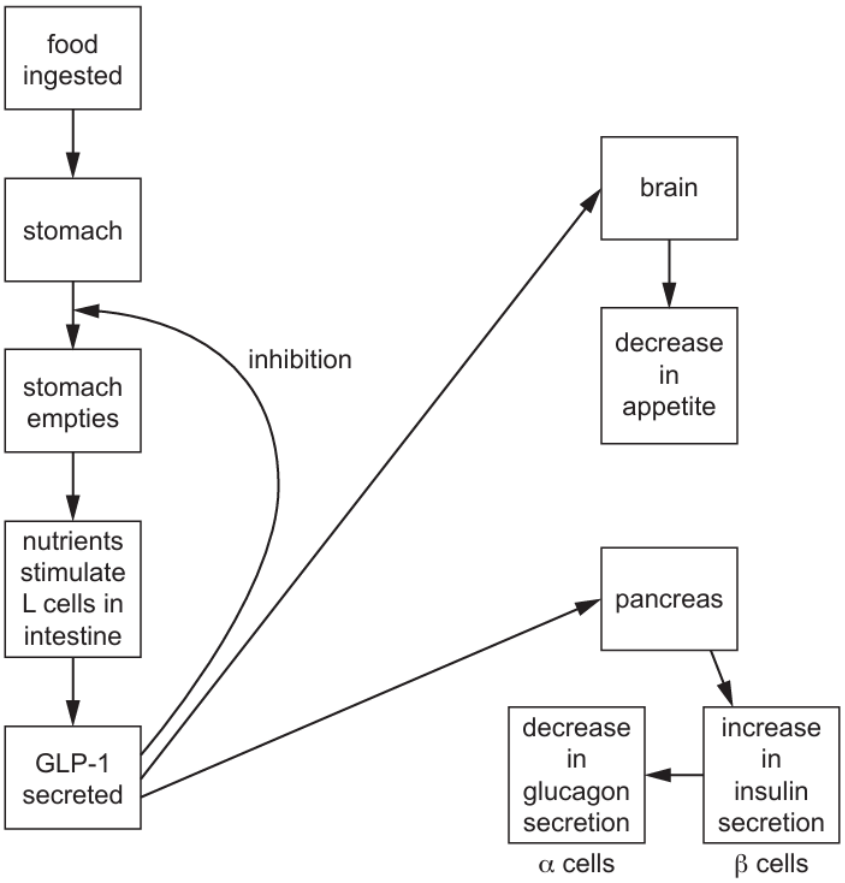


Fig. 6.1

(c) Suggest **one** reason why GLP-1 causes a decrease in appetite.

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18 **(a)** Nerves consist of bundles of different types of neurones.

Fig. 5.1 shows the mean transmission speed of impulses for three types of sensory neurone, **C**, **A$^{\delta}$** and **A$^{\beta}$**.

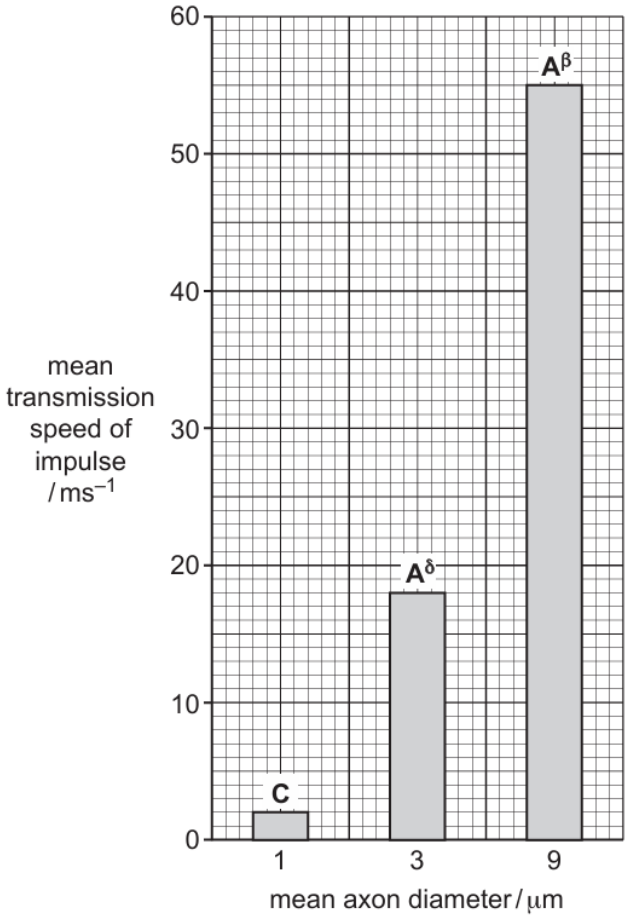


Fig. 5.1

- Impulses from pain receptors in the skin are sent along sensory neurones **C** and **A$^{\delta}$**.
- Sensory neurones **C** and **A$^{\delta}$** synapse in the spinal cord with relay neurones known as projection neurones.
- Projection neurones send impulses to the part of the brain that perceives pain.

- Impulses from touch receptors in the skin pass along sensory neurones **A$^{\beta}$**, which can also synapse with the projection neurones in the spinal cord.

- Sensory neurones **A$^{\delta}$** and **A$^{\beta}$** are myelinated.
- Sensory neurones **C** are unmyelinated.

(i) Describe the results shown in Fig. 5.1 **and** suggest explanations for these results.

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(ii) Gently rubbing a damaged area of skin can reduce the perception of pain.

Suggest an explanation for this.

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(b) Back pain in humans can be reduced by using a transcutaneous electrical nerve stimulation (TENS) machine.

A TENS machine uses electrical impulses to stimulate nerve endings near the site of the pain.

It is thought that TENS triggers the release of natural painkillers called endorphins at synapses.

Fig. 5.2 shows synapses in a pain pathway.

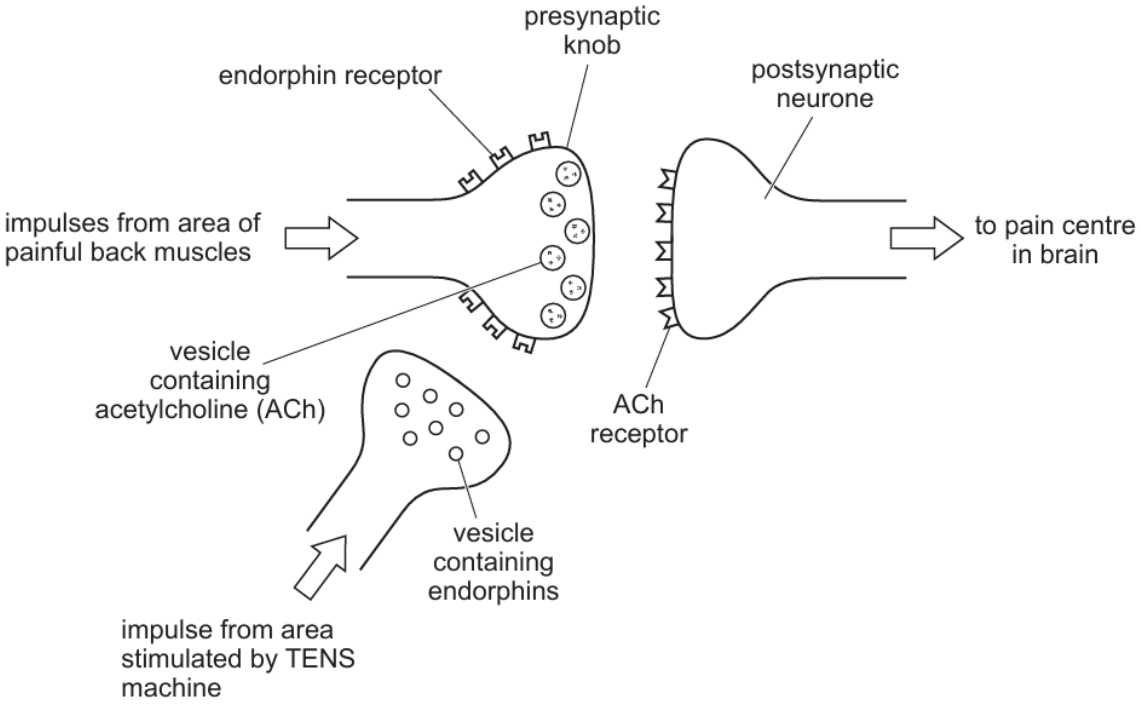


Fig. 5.2

(i) Suggest **and** explain how endorphins may act to reduce pain.

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(ii) Suggest **one disadvantage** of using pharmaceutical drugs for reducing pain compared to using TENS.

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19 **(a)** A person who has a wound to their skin may experience pain. Opioid drugs can be taken to relieve the pain.

Opioid receptors are located in the presynaptic membrane of a cholinergic synapse.

Fig. 6.1 shows the action of an opioid drug on the presynaptic membrane.

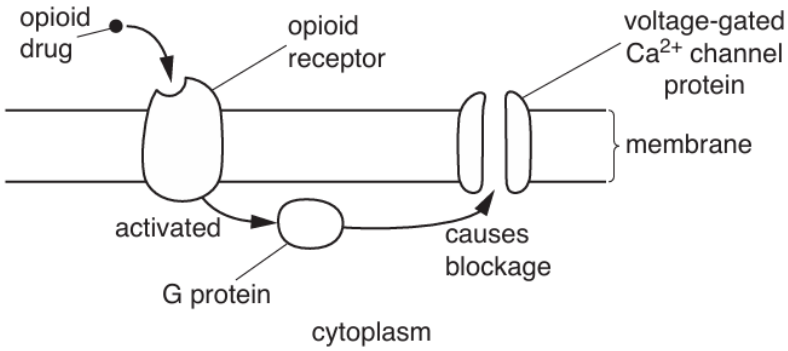


Fig. 6.1

Explain how the action of an opioid drug on the presynaptic membrane can prevent the generation of pain impulses in the postsynaptic neurone.

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..... [5]

(b) Spinal reflexes help the body to respond very quickly to potentially dangerous situations that could cause injury.

(i) State **two** features of a spinal reflex, **other than** being fast.

.....

.....

.....

..... [2]

(ii) Sensory and motor neurones are involved in a spinal reflex.

State the location of the cell body of a sensory neurone **and** a motor neurone.

sensory neurone .....

motor neurone .....

[2]

(iii) Describe the function in a spinal reflex of a sensory neurone **and** a motor neurone.

sensory neurone .....

.....

.....

.....

motor neurone .....

.....

.....

.....

[4]

20 **(a)** **(i)** Identify the precise location in a cholinergic synapse that is described in each of the statements.

A region that contains many mitochondria.

.....

A region where exocytosis of ACh occurs.

.....

A region that contains voltage-gated channel proteins.

.....

A region that contains ligand-gated channel proteins.

.....

[4]

(ii) Outline the roles of synapses in the nervous system.

.....

.....

.....

..... [2]

(b) Some insecticides contain compounds called organophosphates. Organophosphates can act as enzyme inhibitors in neuromuscular junctions.

People who use organophosphates and do not follow safety guidelines are at risk of organophosphate poisoning, which affects muscle function.

Suggest how organophosphates could affect muscle function in humans.

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..... [4]

(c) Outline the role of the sarcoplasmic reticulum in the contraction of striated muscle.

.....

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.....

.....

..... [2]

21 The Venus fly trap, *Dionaea muscipula*, is a carnivorous plant, native to wetlands of the East Coast of the USA. Mineral ions from decayed organisms are often washed away in these wetlands.

Fig. 7.1 shows a Venus fly trap leaf.

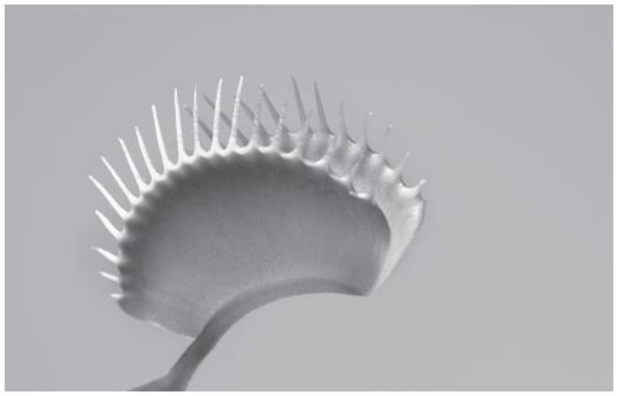


Fig. 7.1

(c) Fig. 7.2 is a graph of an action potential in a human neurone.

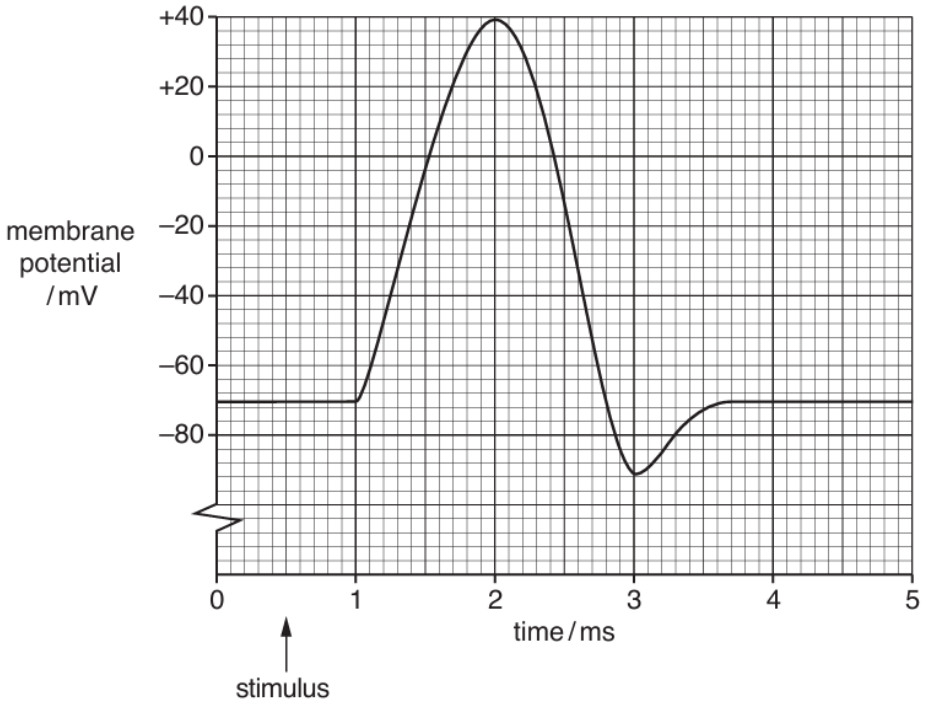


Fig. 7.2

Fig. 7.3 is a graph of an action potential in leaf cells of a Venus fly trap.

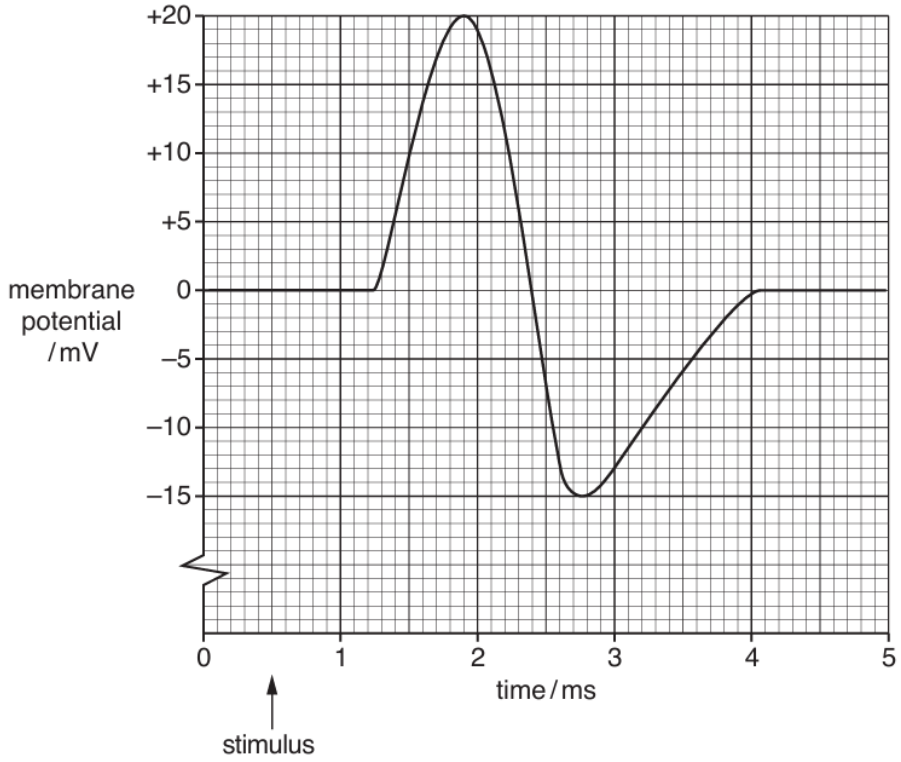


Fig. 7.3

With reference to Fig. 7.2 and Fig. 7.3, describe how the action potential of the Venus fly trap differs from that of a human.

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..... [3]

22 **(a)** Fig. 1.1 is an electron micrograph showing a cross-section of a myelinated neurone.

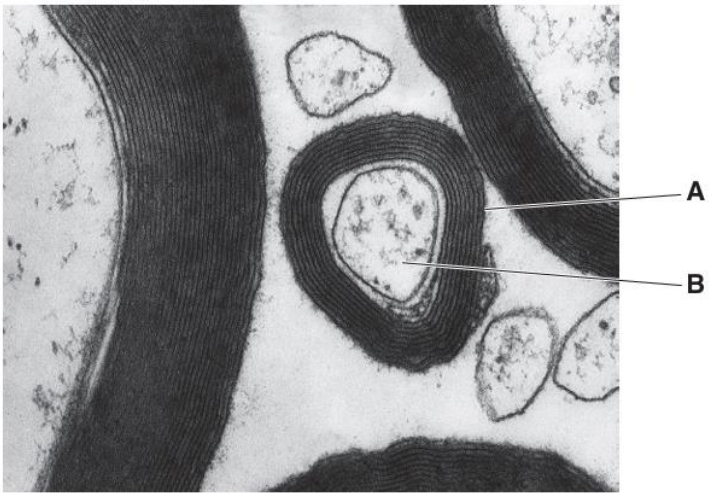


Fig. 1.1

Name **A** and **B**.

A .....

B .....

[2]

(b) Explain what is meant by saltatory conduction **and** describe its effect on the transmission of a nerve impulse.

.....

.....

.....

.....

.....

..... [3]

(c) A type of sea snail, *Conus purpurascens*, produces a toxin that blocks calcium ion channels in the presynaptic knob of a cholinergic synapse. The presence of this toxin results in no action potentials in the postsynaptic neurone.

Explain why the presence of this toxin results in **no** action potentials in the postsynaptic neurone.

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..... [5]

23 **(a)** Describe how an action potential arriving at a presynaptic neurone can result in the release of acetylcholine into the synaptic cleft.

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.....[4]

(b) Lidocaine is a local anaesthetic drug which blocks voltage-gated Na^+ channels in the postsynaptic membrane of a synapse.

Explain the effect of lidocaine action on the postsynaptic neurone.

.....

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.....[2]

(c) Fig. 8.1 is a diagram of a neuromuscular junction.

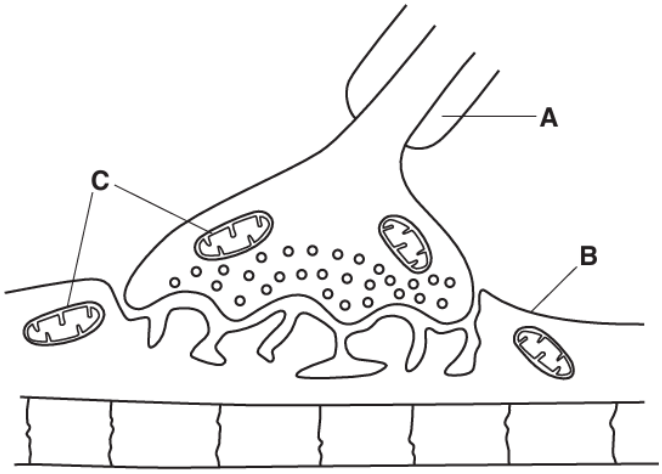


Fig. 8.1

(i) With reference to Fig. 8.1, name structures **A**, **B** and **C**.

A .....

B .....

C ..... [3]

(ii) Outline the importance of structure **A** in the transmission of nerve impulses.

.....

.....

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.....

.....[2]

(iii) Explain why the structures labelled **C** are needed in a neuromuscular junction.

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.....[4]

24 **(a)** In mammals, the nervous system and the endocrine system coordinate responses to the changes in internal and external environments.

Complete Table 8.1 to indicate the differences between the nervous system and the endocrine system.

Table 8.1

feature	nervous system	endocrine system
method of communication	.....	.....
method of transmission	.....	.....
transmission speed	.....	.....
duration of effect	.....	.....

[4]

25 **(a)** Outline the roles of sensory receptor cells in the mammalian nervous system.

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..... [3]

(b) Fig. 8.1 shows the changes in potential difference (p.d.) across the membrane of a receptor cell over a period of time. The membrane was stimulated at time **A** and at time **B** with stimuli of different intensities.

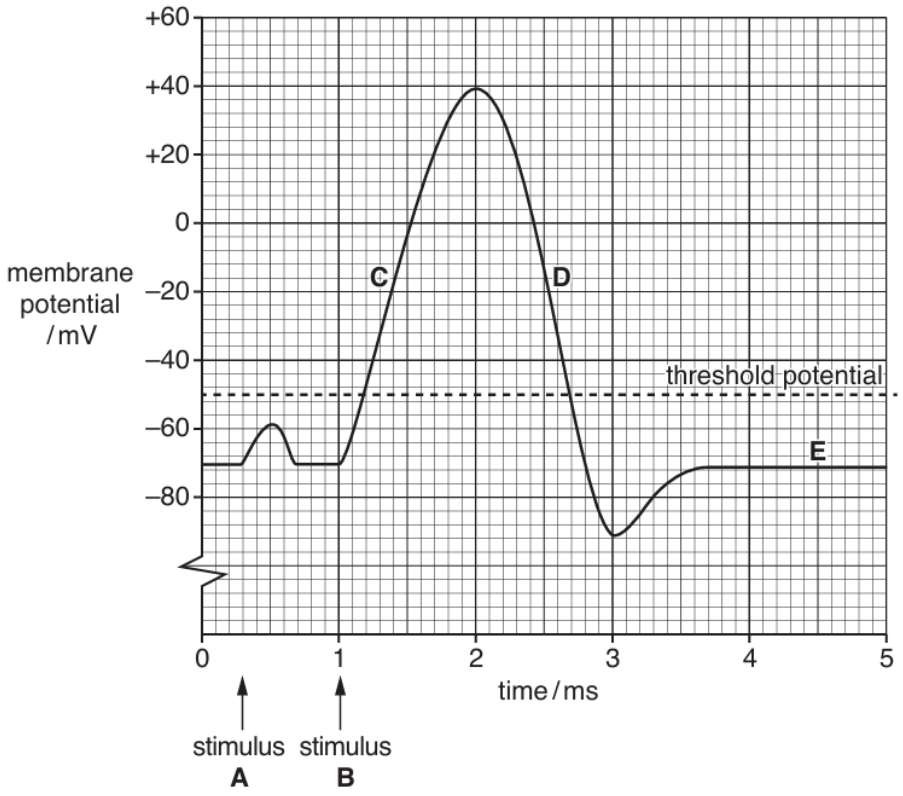


Fig. 8.1

(i) State which of the letters **C**, **D** and **E** on Fig. 8.1 correspond to each of these events. You may use each of the letters **C**, **D** or **E** once, more than once or not at all.

The Na^+/K^+ pump is operating .....

The voltage-gated Na^+ channels are open .....

The voltage-gated K^+ channels are open .....

[3]

(ii) Explain why stimulus **A** did not result in an action potential being produced whereas stimulus **B** did.

.....

.....

.....

..... [2]

(iii) Describe the importance of the refractory period in the transmission of action potentials.

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.....

..... [2]

(iv) Describe how action potentials are transmitted along a myelinated axon.

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..... [4]