AQA A-LEVEL · 7402

# BIOLOGY



## EXAM QUESTION PACK

### 3.6.2.2 SYNAPTIC TRANSMISSION

| SCORE | PERCENTAGE |
| --- | --- |
| /203 | % |

STEMUP

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## Q1.

(a) Dopamine is a neurotransmitter released in some synapses in the brain. The transmission of dopamine is similar to that of acetylcholine.

Dopamine stimulates the production of nerve impulses in postsynaptic neurones.

Describe how.

Do **not** include in your answer the events leading to the release of dopamine and the events following production of nerve impulses at postsynaptic neurones.

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**(3)**

(b) Dopamine has a role in numerous processes in the brain including pain relief. The release of dopamine can be stimulated by chemicals called endorphins produced in the brain. Endorphins attach to opioid receptors on presynaptic neurones that release dopamine.

Morphine is a drug that has a similar structure to endorphins and can provide pain relief.

Explain how.

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**(2)**

(c) GABA is a neurotransmitter released in some inhibitory synapses in the brain. GABA causes negatively charged chloride ions to enter postsynaptic neurones.

Explain how this inhibits postsynaptic neurones.

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**(3)**

**(Total 8 marks)**

## Q2.

Alzheimer's disease (AD) is a non-reversible brain disorder that develops over a number of years. At the start of 2014 the number of Americans with AD was estimated to be 5.4 million. Every 30 seconds another person in America develops AD.

In the brain of a person with AD there is a lower concentration of acetylcholine. This affects communication between nerve cells and initially results in memory loss and confusion. Some of the symptoms of AD that are associated with communication between nerve cells are reduced by taking the drug donepezil. Donepezil inhibits the enzyme acetylcholinesterase.

A gene mutation called E280A found on chromosome 14 causes early-onset AD at a mean age of 49 years. The age at which the E280A mutation is expressed to cause AD varies.
Yaramul is a town in a historically isolated region of the Andes Mountains. The population of this town has the highest frequency of the E280A mutation in the world. The origin of the E280A mutation in this population has been traced back to a common ancestor in the 17th century. Natural selection has not reduced the frequency of the E280A mutation in the population.

This autosomal dominant mutation involves a change in triplet 280 from GAA to GCA. Scientists analysed chromosome 14 from 102 individuals from Yaramul. They recorded a sample size of 204 and detected 75 E280A mutations but only 74 potential AD cases. The scientists identified individuals with the mutation by whole genome sequencing. They had decided that a DNA probe would not be a suitable method to detect the E280A mutation.

(a) Assuming no one with AD died in 2014, calculate the annual percentage increase in

AD cases in America for 2014 (lines 2–4).

Answer = _____ %

**(2)**

(b) Explain how donepezil could improve communication between nerve cells (lines 7–9).

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**(3)**

(c) Suggest and explain **two** reasons why there is a high frequency of the E280A mutation in Yaramul (lines 13–15).

1. _____

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2. _____

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**(2)**

(d) Explain why natural selection has **not** reduced the frequency of the E280A mutation in the population (lines 16–17).

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**(2)**

(e) The age at which the E280A mutation is expressed to cause AD can vary (lines 11–12).

Suggest and explain **one** reason for this.

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**(2)**

(f) One scientific study which analysed chromosome 14 involved 102 individuals. The scientists recorded a sample size of 204. In this sample they detected 75 E280A mutations but only 74 potential AD cases (lines 19–21).

Suggest explanations for the figures the scientists recorded.

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**(2)**

(g) Suggest why a DNA probe for the mutated triplet was **not** considered a suitable method for detection of the E280A mutation (lines 22–23).

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**(2)**

**(Total 15 marks)**

## Q3.

(a) When a nerve impulse arrives at a synapse, it causes the release of neurotransmitter from vesicles in the presynaptic knob.

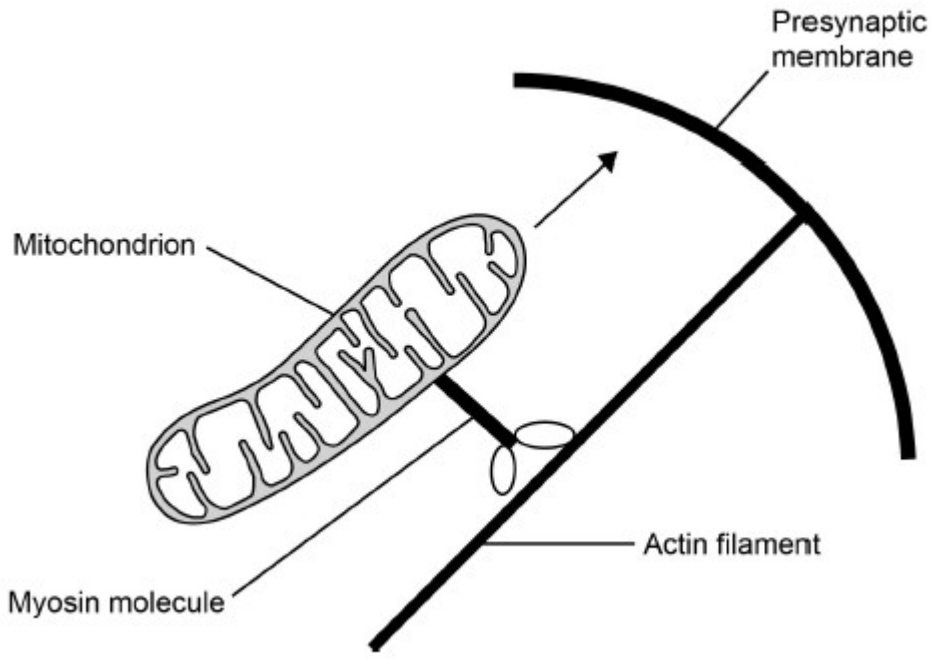
Describe how.

_____

**(3)**

(b) The presynaptic knob contains actin filaments and myosin molecules.

The myosin molecules can attach to mitochondria and move them towards the presynaptic membrane, as shown in the diagram.




Use your knowledge of how myosin and actin interact to suggest how the myosin molecule moves the mitochondrion towards the presynaptic membrane.

Do **not** include the roles of calcium ions and tropomyosin in your answer.

_____

**(2)**

(c) This movement of mitochondria happens when nerve impulses arrive at the synapse.

Suggest and explain **one** advantage of the movement of mitochondria towards the presynaptic membrane when nerve impulses arrive at the synapse.

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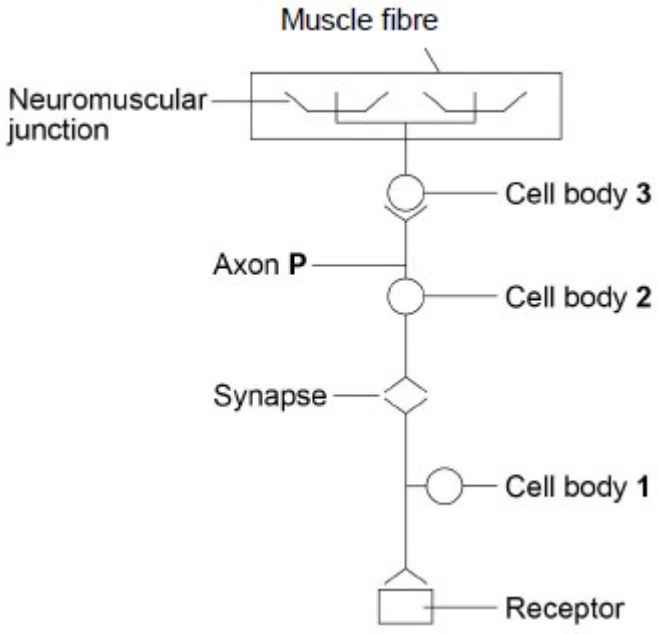
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**(2)**

**(Total 7 marks)**

## Q4.

The diagram below shows a nerve pathway in an animal.




(a) The nerve pathway shown in the diagram may be regarded as a simple reflex arc.

Use the diagram to explain why.

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**(1)**

(b) Suggest **two** advantages of simple reflexes.

1. _____

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2. _____

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**(2)**

(c) In the nerve pathway in the diagram, synapses ensure that nerve impulses only travel towards the muscle fibre.

Explain how.

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**(2)**

(d) Axon **P** was found to conduct impulses much faster than other axons in the nerve pathway shown in the diagram.

Describe and explain **one** feature of axon **P** that might cause this difference.

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**(2)**

**(Total 7 marks)**

## Q5.

(a) Describe the roles of calcium ions and ATP in the contraction of a myofibril.

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**(5)**

(b) ATP is an energy source used in many cell processes. Give **two** ways in which ATP is a suitable energy source for cells to use.

1. _____

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2. _____

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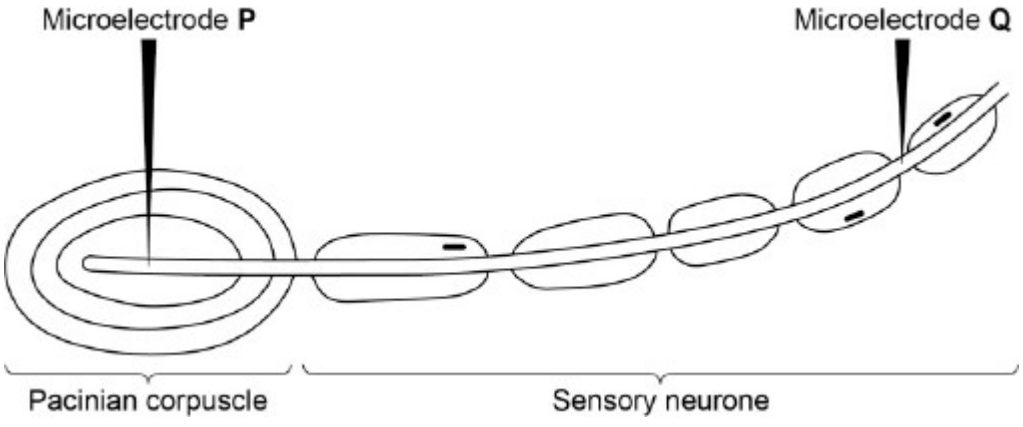
**(2)**

**(Total 7 marks)**

## Q6.

A biologist investigated the stimulation of a Pacinian corpuscle in the skin of a fingertip. She used microelectrodes to measure the maximum membrane potential of a Pacinian corpuscle and its sensory neurone when different pressures were applied to the fingertip.

The figure below shows the Pacinian corpuscle, its sensory neurone and the position of the microelectrodes.



The table below shows some of the biologist's results.

| Pressure applied to the fingertip | Membrane potential at P / millivolts | Membrane potential at Q / millivolts |
|---|---|---|
| None | –70 | –70 |
| Light | –50 | –70 |
| Medium | +30 | +40 |
| Heavy | +40 | +40 |

(a) Explain how the resting potential of –70 mV is maintained in the sensory neurone when no pressure is applied.

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**(2)**

(b) Explain how applying pressure to the Pacinian corpuscle produces the changes in membrane potential recorded by microelectrode **P**.

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**(3)**

(c) The membrane potential at **Q** was the same whether medium or heavy pressure was applied to the finger tip. Explain why.

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**(2)**

(d) Multiple sclerosis is a disease in which parts of the myelin sheaths surrounding neurones are destroyed. Explain how this results in slower responses to stimuli.

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**(2)**

**(Total 9 marks)**

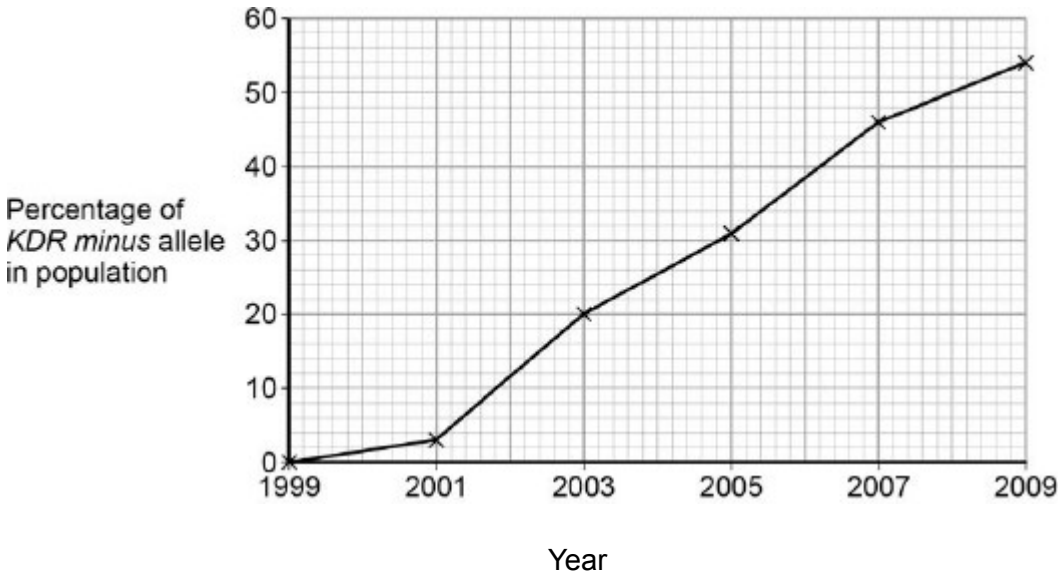
## Q7.

Malaria is a disease that is spread by insects called mosquitoes. In Africa, DDT is a pesticide used to kill mosquitoes, to try to control the spread of malaria.

Mosquitoes have a gene called *KDR*. Today, some mosquitoes have an allele of this gene, *KDR minus*, that gives them resistance to DDT. The other allele, *KDR plus*, does not give resistance.

Scientists investigated the frequency of the *KDR minus* allele in a population of mosquitoes in an African country over a period of 10 years.

The figure below shows the scientists' results.




(a) Use the Hardy–Weinberg equation to calculate the frequency of mosquitoes heterozygous for the *KDR* gene in this population in 2003.

Show your working.

Frequency of heterozygotes in population in 2003 _____

**(2)**

(b) Suggest an explanation for the results in the figure above.

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**(4)**

The *KDR plus* allele codes for the sodium ion channels found in neurones.

(c) When DDT binds to a sodium ion channel, the channel remains open all the time. Use this information to suggest how DDT kills insects.

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**(2)**

(d) Suggest how the *KDR minus* allele gives resistance to DDT.

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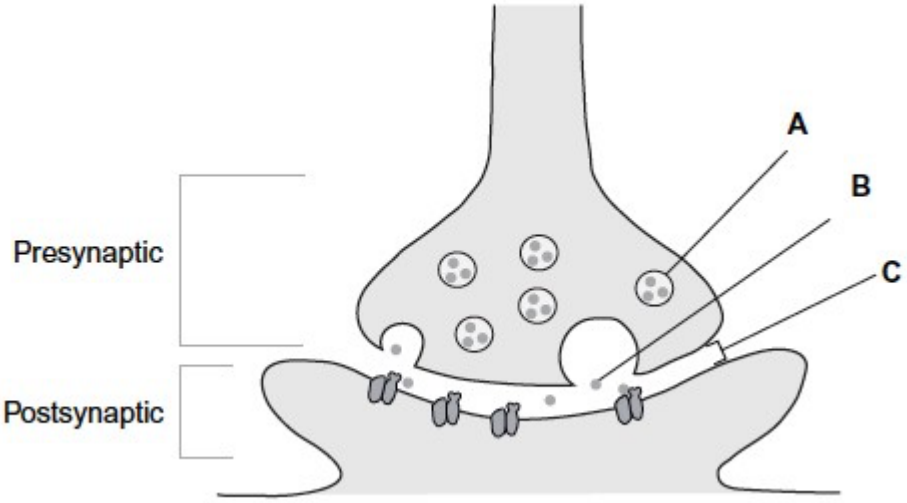
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**(2)**

**(Total 10 marks)**

## Q8.

The blink reflex involves synapses. Below is a diagram of a synapse.




Identify **A**, **B** and **C**.

**A** _____

**B** _____

**C** _____

**(Total 3 marks)**

## Q9.

(a) The blink reflex is caused by stimulation of receptors in the eye or eyelid. Suggest **two** types of stimuli to which these receptors might respond.

1. _____

2. _____

**(1)**

(b) In humans, resting blink rate varies widely from 8 to 24 blinks per minute. This variation could result in the investigations into effect of stimulation on blink rate producing means that are **not** significantly different. Explain why.

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**(2)**

(c) Some diseases cause changes in blink rate. Doctors do **not** often use blink rate to diagnose these diseases. Suggest **two** reasons why.

1

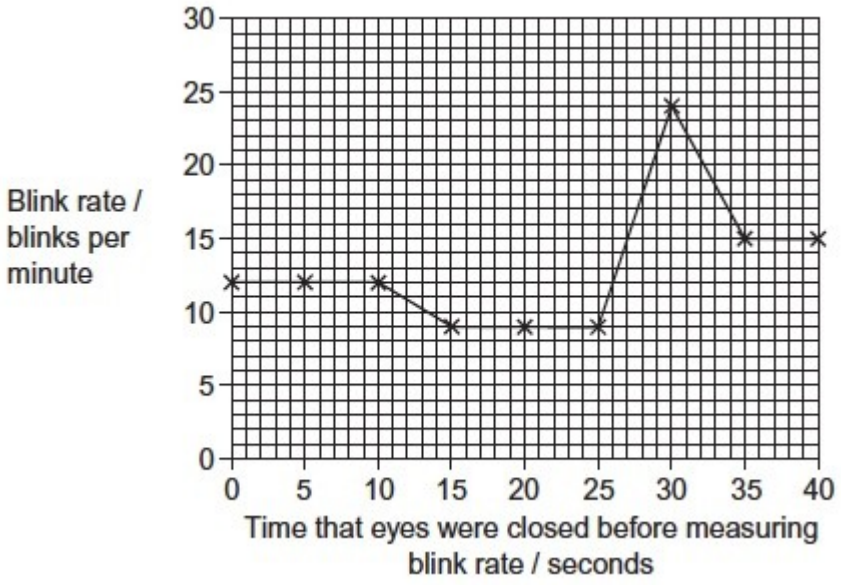
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2

**(2)**

(d) A student completed an investigation to determine if the length of time eyes are closed before opening them affected blinking rate. His results are shown below.




The student did **not** draw a line of best fit.
Suggest **two** reasons why.

1

2

**(2)**

(e) The student did **not** carry out repeats. He was still able to carry out a statistical test.
Explain why.

**(1)**

(f) The blink reflex can be stopped by drugs which prevent the opening of sodium ion channel proteins in the axons of motor neurones.
Suggest how these drugs affect the passage of nerve impulses along the axons.

**(2)**

(g) The blink reflex involves synapses. Channel proteins on presynaptic neurones are involved in reflex responses.
Explain how.

**(3)**

(h) A student wanted to investigate the resting blink rate in people 60 years of age and people 15 years of age.
Describe how the student could find out whether there was a significant difference in blink rates between the two age groups.

**(3)**
**(Total 16 marks)**

## Q10.

The blink reflex can be affected by anaesthetics. Local anaesthetics are used to stop people feeling pain but do not make them unconscious. General anaesthetics make people unconscious and stop them feeling pain.

Doctors investigated two ways of measuring the effect of general anaesthetics.

They gave:

- anaesthetic **S** to 18 people
- anaesthetic **Q** to 29 people

They recorded how long it took for the people to stop blinking.

The doctors then repeated the investigation. This time, they used a machine that measures brain activity to decide when a person was unconscious, rather than when blinking stopped. For each person, they recorded how long it took for the machine's readings to show that the person was unconscious.

Their results are shown in the table. A value of ±2 × SD from the mean includes over 95% of the data.

| Anaesthetic | Mean time taken to stop blinking / minutes (±2 × SD) | Mean time taken for machine to show that person was unconscious / minutes (±2 × SD) |
|---|---|---|
| **S** | 0.24 (±0.01) | 0.48 (±0.11) |
| **Q** | 0.28 (±0.02) | 0.44 (±0.07) |

(a) Blinking involves cholinergic synapses. Anaesthetic **S** is a similar shape to acetylcholine. Suggest how anaesthetic **S** stops the transmission across the synapse.

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**(3)**

(b) Should time taken to stop blinking be used as an indicator of when to start surgery? Explain your answer.

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**(2)**

(c) Each person was given the same volume of anaesthetic per kg of body mass.
Suggest why.

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**(1)**

**(Total 6 marks)**

## Q11.

(a) The following statements are about events during an action potential.

**A** Potassium ions diffuse out across the neurone membrane.
**B** Sodium ions diffuse in across the neurone membrane.
**C** Sodium ion channels open.
**D** Active transport of sodium and potassium ions restores resting potential.
**E** Potassium ion channels open.
**F** Hyperpolarisation of the membrane occurs.

(i) Which of the events, **A** to **F**, starts depolarisation?
Put the correct letter in the box.

**(1)**

(ii) Which of the events, **A** to **F**, requires the hydrolysis of ATP?
Put the correct letter in the box.

**(1)**

(b) Synaptophysin is a protein involved in the production of synaptic vesicles.

Scientists can use the presence or absence of synaptophysin to identify presynaptic and postsynaptic membranes in synapses.

Explain why they are able to use synaptophysin for this purpose.

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**(1)**

(c) Dopamine is a neurotransmitter. Production of too much dopamine is associated with schizophrenia. A drug used to treat schizophrenia binds to dopamine receptors in synapses. This binding does not lead to the formation of an action potential.

(i) Suggest why the drug used to treat schizophrenia is able to bind to the same receptor as dopamine.

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**(1)**

(ii) Suggest why binding of the drug does **not** lead to production of an action potential.

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**(2)**

**(Total 6 marks)**

## Q12.

Multiple sclerosis (MS) is a disease that involves damage to the myelin sheaths of neurones. Movement in MS sufferers may be jerky or slow.

(a) Damage to the myelin sheaths of neurones can lead to problems controlling the contraction of muscles.

Suggest **one** reason why.

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**(2)**

Scientists investigated the use of substances called cannabinoids to control muscle problems caused by MS.

(b) Cannabinoids are hydrophobic molecules. In the body, they easily pass into neurones.
Explain why.

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**(1)**

(c) Cannabinoid receptors are found in the **pre-synaptic** membrane of neuromuscular junctions. When a cannabinoid binds to its receptor, it closes calcium ion channels.

Suggest how cannabinoids could prevent muscle contraction.

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**(4)**

(d) Cannabinoids include substances found in cannabis that can enter brain tissue. Scientists are developing artificial cannabinoids that can enter neuromuscular junctions but cannot enter brain tissue.

Suggest why these artificial cannabinoids would be better to use than cannabis when treating someone with MS.

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**(2)**

**(Total 9 marks)**

## Q13.

The body loses heat quickly in cold water. A researcher investigated the effect of length of time in a bath of ice-cold water on the reaction times of 20 healthy people aged between 21 and 23 years of age.

She measured each person's reaction time after being left in ice-cold water for 15, 30 or 45 seconds. She also recorded each person's reaction time before being placed in the ice-cold water (0 seconds).

The table shows her results.

| Length of time in bath of ice-cold water / seconds | Mean reaction time / seconds | Standard error |
|---|---|---|
| **0** | 0.395 | 0.0124 |
| **15** | 0.301 | 0.0105 |
| **30** | 0.297 | 0.0212 |
| **45** | 0.326 | 0.0183 |

(a) (i) One reason that reaction time is slower when body temperature falls is because nerve impulse conduction is slower. Explain how a lower temperature leads to slower nerve impulse conduction.

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**(2)**

(ii) Other than temperature, give **two** factors that affect the speed of nerve impulse conduction.

1. _____

2. _____

**(2)**

(b) Suggest the conditions that the researcher used when obtaining her data for 0 seconds.

_____

_____

_____

**(1)**

(c) Explain how the researcher could use her **raw** data to find

(i) the mode_____

_____

(ii) the range_____

_____

**(2)**

(d) A student reading the researcher's report concluded that the difference between the results for 30 seconds and 45 seconds was significant. Do you agree with his

conclusion? Explain your answer.

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**(3)**

**(Total 10 marks)**

## Q14.

Serotonin is a neurotransmitter released in some synapses in the brain. It is transported back out of the synaptic gap by a transport protein in the pre-synaptic membrane.

(a) Serotonin diffuses across the synaptic gap and binds to a receptor on the post-synaptic membrane.

Describe how this causes depolarisation of the post-synaptic membrane.

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**(2)**

(b) It is important that a neurotransmitter such as serotonin is transported back out of synapses. Explain why.

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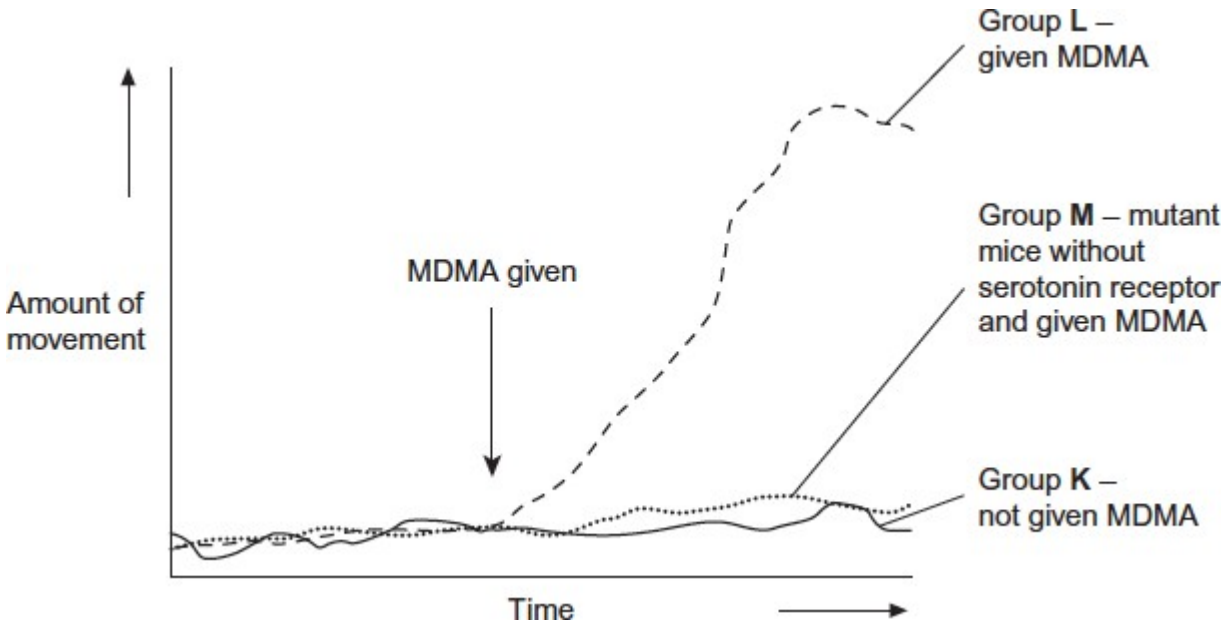
**(2)**

(c) Scientists investigated the effect of a drug called MDMA on movement of mice. They measured the amount of movement of three groups of mice, **K, L** and **M.**

- Group **K,** mice not given MDMA.
- Group **L,** mice given MDMA.

- Group **M,** mutant mice that did not produce a serotonin receptor on their post-synaptic membranes and were given MDMA.

The graph shows their results.




The scientists concluded that MDMA affects movement by binding to serotonin receptors.

How do these results support this conclusion?

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**(3)**

**(Total 7 marks)**

## Q15.

The black mamba is a poisonous snake. Its poison contains a toxin.

The table shows the base sequence of mRNA that codes for the first two amino acids of this toxin.

| | | | | | | |
|---|---|---|---|---|---|---|
| Base sequence of anticodon on tRNA | | | | | | |
| Base sequence of mRNA | **A** | **C** | **G** | **A** | **U** | **G** |
| Base sequence of DNA | | | | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | | | | |

Complete the table to show

(a) (i) the base sequence of the anticodon on the first tRNA molecule that would bind to this mRNA sequence

**(1)**

(ii) the base sequence of the DNA from which this mRNA was transcribed.

**(1)**

(b) The length of the section of DNA that codes for the complete toxin is longer than the mRNA used for translation. Explain why.

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**(1)**

(c) A mutation in the base sequence of the DNA that codes for the toxin would change the base sequence of the mRNA.

Explain how a change in the base sequence of the mRNA could lead to a change in the tertiary structure of the toxin.

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**(1)**

(d) The black mamba's toxin kills prey by preventing their breathing. It does this by inhibiting the enzyme acetylcholinesterase at neuromuscular junctions. Explain how this prevents breathing.

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**(3)**

**(Total 7 marks)**

## Q16.

Different substances are involved in coordinating responses in animals.

(a) Synapses are unidirectional. Explain how acetylcholine contributes to a synapse being unidirectional.

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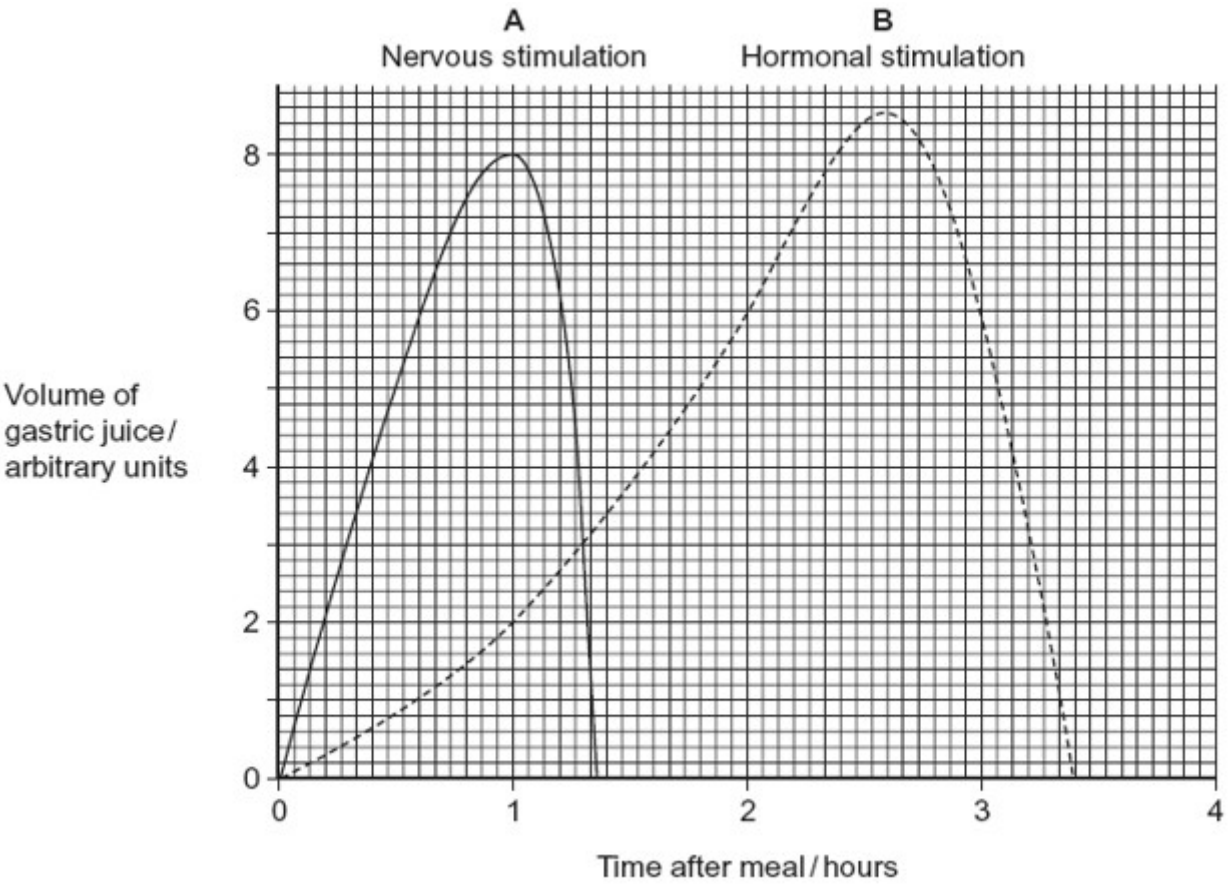
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**(2)**

(b) Cells in the stomach wall release gastric juice after a meal. The graph shows how the volumes of gastric juice produced by nervous stimulation and by hormonal stimulation change after a meal.




(i) Describe the evidence from the graph that curve **A** represents the volume of gastric juice produced by nervous stimulation.

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**(2)**

(ii) Complete the table to show the percentage of gastric juice produced by nervous stimulation at the times shown.

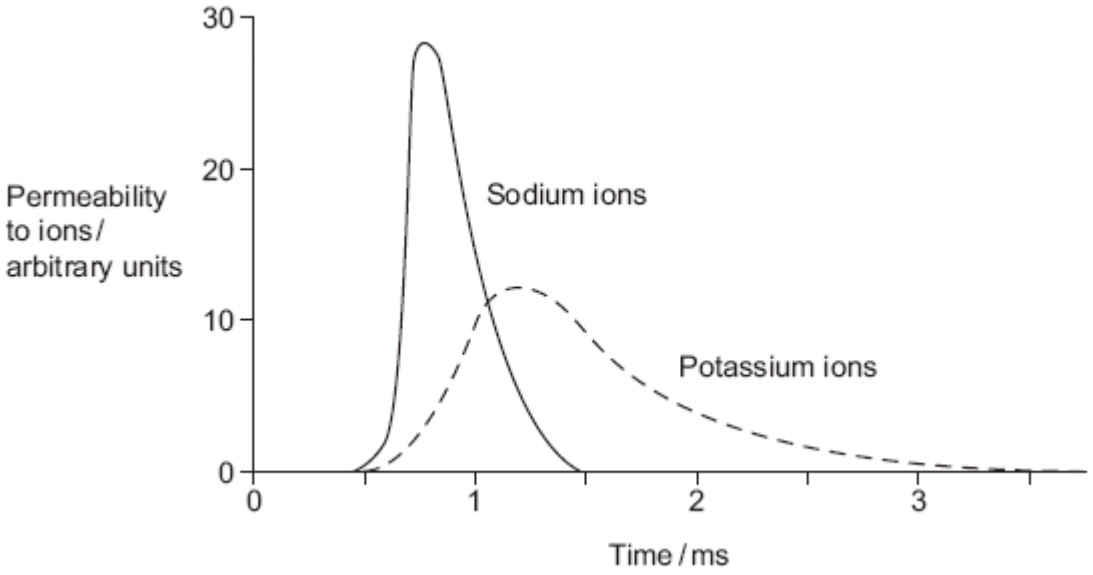
| | Time after meal / hours | | |
|---|---|---|---|
| | **1** | **2** | **3** |
| Percentage of gastric juice produced by nervous stimulation | | | |

**(1)**

**(Total 5 marks)**

## Q17.

During an action potential, the permeability of the cell-surface membrane of an axon changes. The graph shows changes in permeability of the membrane to sodium ions ($Na^+$) and to potassium ions ($K^+$) during a single action potential.




(a) Explain the shape of the curve for sodium ions between 0.5 ms and 0.7ms.

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**(3)**

(b) During an action potential, the membrane potential rises to +40 mV and then falls.

Use information from the graph to explain the fall in membrane potential.

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**(3)**

(c) After exercise, some ATP is used to re-establish the resting potential in axons. Explain how the resting potential is re-established.

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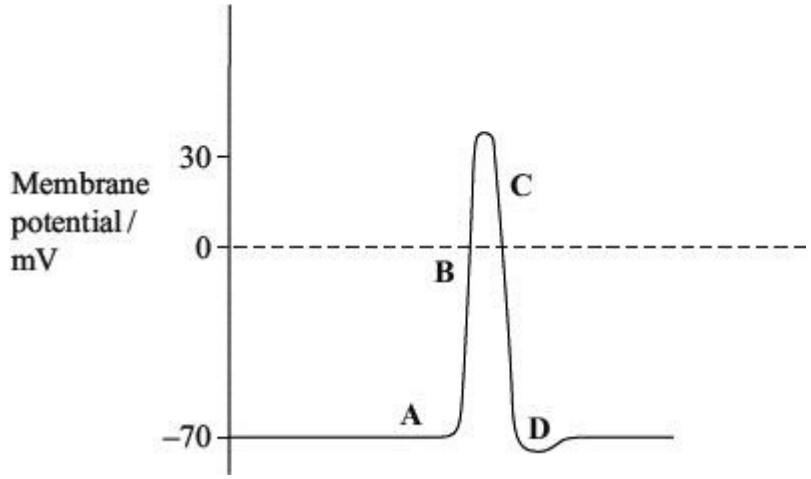
**(2)**

**(Total 8 marks)**

## Q18.

(a) **Figure 1** shows the changes in membrane potential at one point on an axon when an action potential is generated.

**Figure 1**




The changes shown in **Figure 1** are due to the movement of ions across the axon membrane. Complete the table by giving the letter (**A** to **D**) that shows where each process is occurring most rapidly.

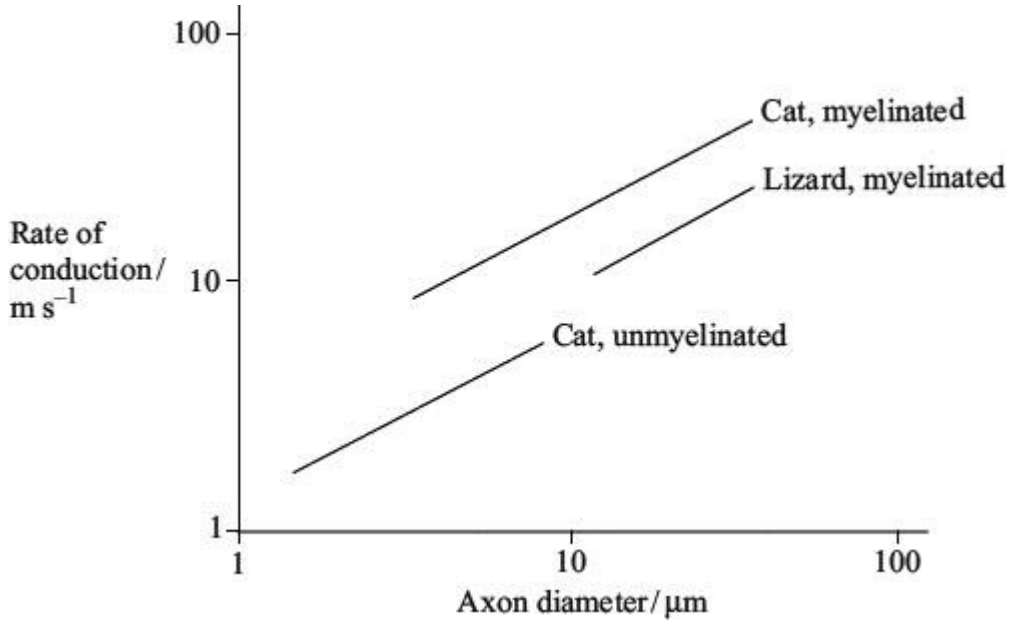
| Process | Letter |
|---|---|

| | |
|---|---|
| Active transport of sodium and potassium ions | |
| Diffusion of sodium ions | |
| Diffusion of potassium ions | |

**(2)**

(b) **Figure 2** shows the relationship between axon diameter, myelination and the rate of conduction of the nerve impulse in a cat (a mammal) and a lizard (a reptile).

**Figure 2**




(i) Explain the effect of myelination on the rate of nerve impulse conduction.

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**(2)**

**S** (ii) For the same diameter of axon, the graph shows that the rate of conduction of the nerve impulse in myelinated neurones in the cat is faster than that in the lizard. Suggest an explanation for this.

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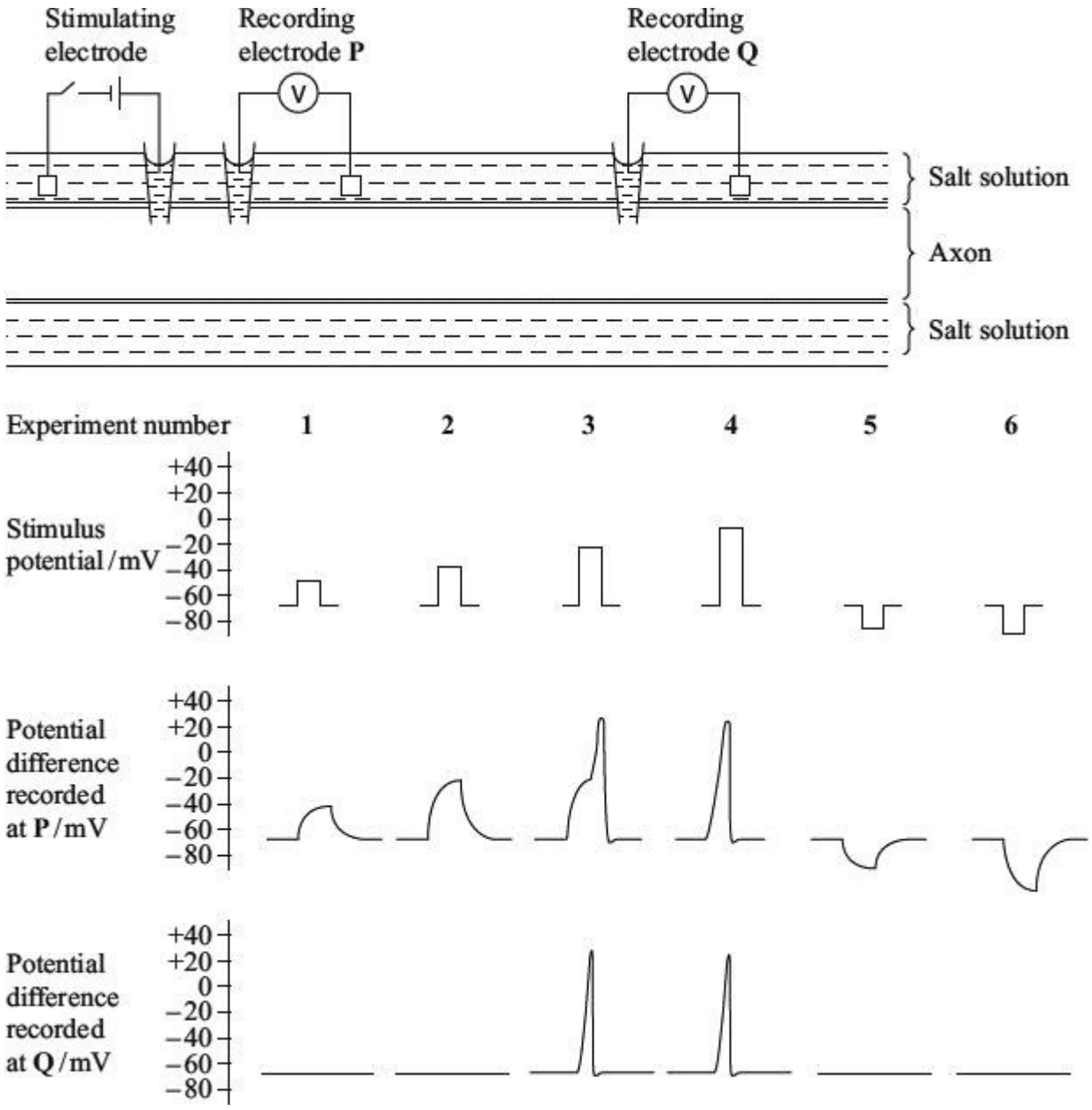
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**(2)**

**Figure 3** shows how a stimulating electrode was used to change the potential difference across an axon membrane. Two other electrodes, **P** and **Q**, were used to record any potential difference produced after stimulation. The experiment was repeated six times, using a different stimulus potential each time. In experiments **1** to **4**, the stimulating voltage made the inside of the axon less negative. In experiments **5** and **6**, it made the inside of the axon more negative.

**Figure 3**




(c) Explain the results of experiments **1** to **4**.

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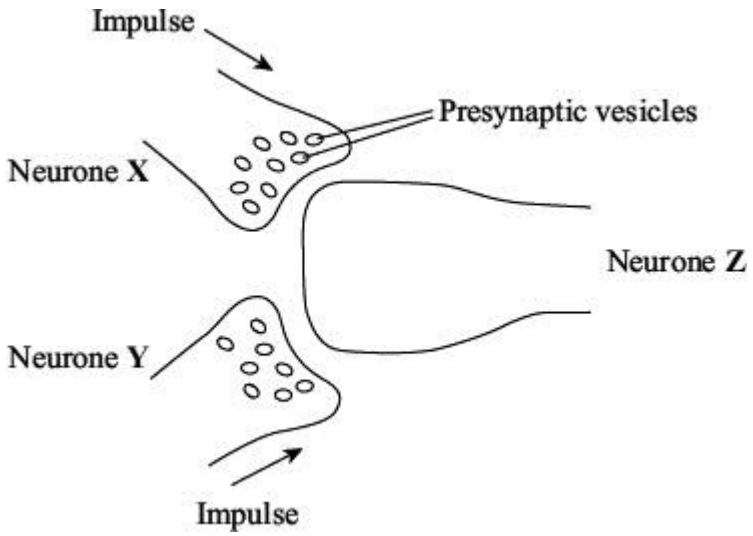
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**(5)**

(d) **Figure 4** shows two neurones, **X** and **Y**, which each have a synapse with neurone **Z**.

**Figure 4**




Neurone **X** releases acetylcholine from its presynaptic vesicles. Neurone **Y** releases a different neurotransmitter substance which allows chloride ions ($Cl^-$) to enter neurone **Z**. Use this information, and information from **Figure 3**, to explain how neurones **X** and **Y** have an antagonistic effect on neurone **Z**.

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**(4)**

**(Total 15 marks)**

## Q19.

Secretion of neurotransmitters into a synaptic cleft may produce an action potential in a postsynaptic neurone.

(i) Explain how the release of acetylcholine at an excitatory synapse reduces the membrane potential of the postsynaptic membrane.

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**(2)**

(ii) Explain what causes transmission at a synapse to occur in only one direction.

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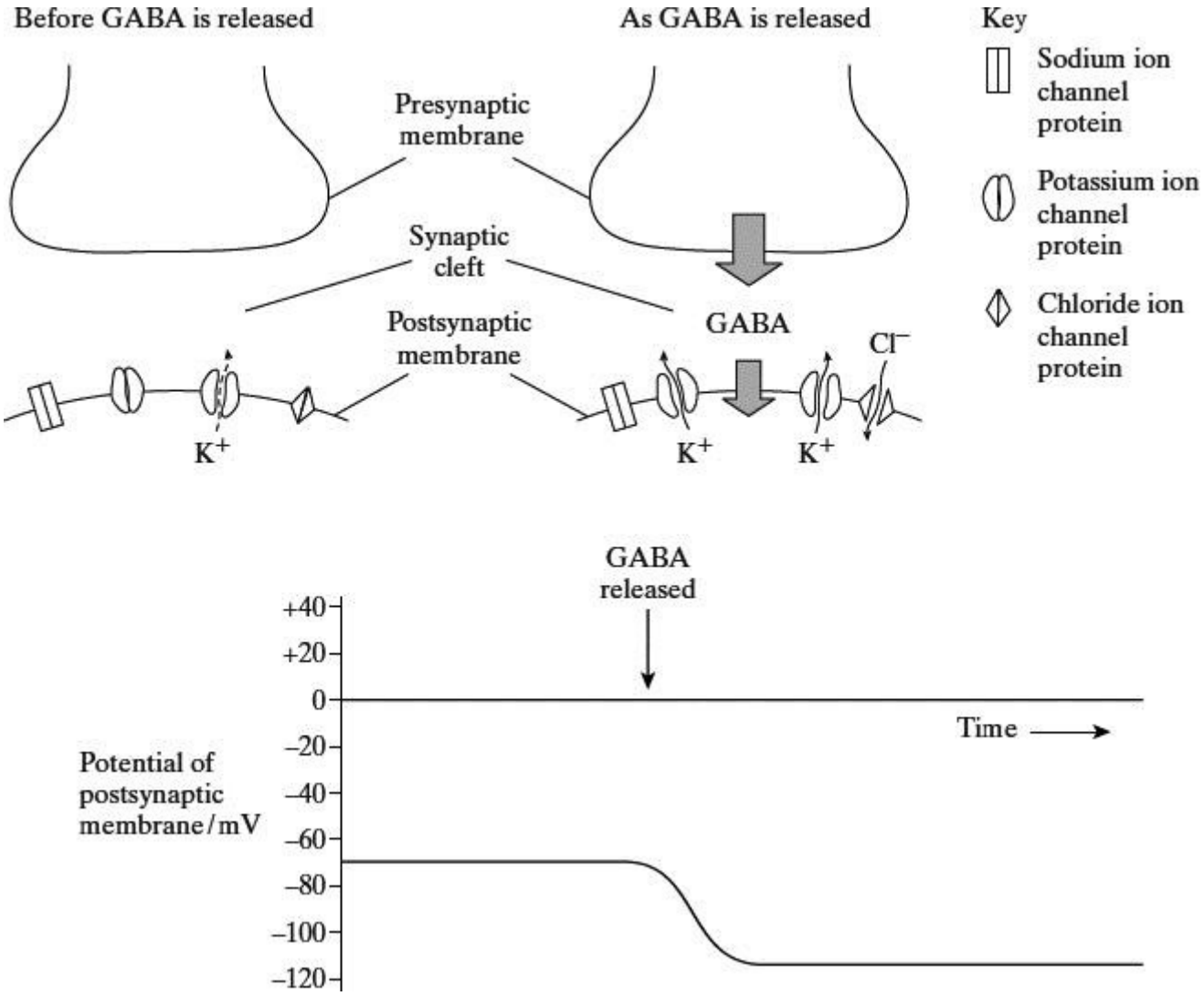
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**(2)**

(iii) GABA is a neurotransmitter which inhibits the production of action potentials. The diagram and the graph show how the release of GABA from a presynaptic membrane affects the membrane potential of a postsynaptic membrane.



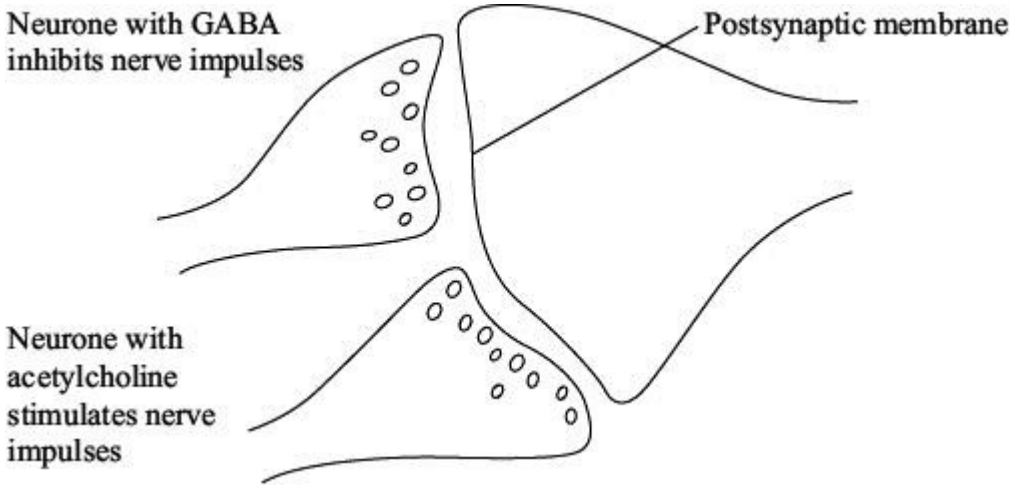

When the postsynaptic membrane is stimulated by acetylcholine, an action potential is less likely if GABA is released at the same time. Explain why.

**(4)**

**(Total 8 marks)**

## Q20.

Acetylcholine is a neurotransmitter which binds to postsynaptic membranes and stimulates the production of nerve impulses. GABA is another neurotransmitter. It is produced by certain neurones in the brain and spinal cord. GABA binds to postsynaptic membranes and inhibits the production of nerve impulses. The diagram shows a synapse involving three neurones.




(a) Describe the sequence of events leading to the release of acetylcholine and its binding to the postsynaptic membrane.

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**(4)**

(b) The binding of GABA to receptors on postsynaptic membranes causes negatively charged chloride ions to enter postsynaptic neurones. Explain how this will inhibit transmission of nerve impulses by postsynaptic neurones.

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**(3)**

(c) Epilepsy may result when there is increased neuronal activity in the brain.

(i) One form of epilepsy is due to insufficient GABA. GABA is broken down on the postsynaptic membrane by the enzyme GABA transaminase. Vigabatrin is a new drug being used to treat this form of epilepsy. The drug has a similar molecular structure to GABA. Suggest how Vigabatrin may be effective in treating this form of epilepsy.

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**(2)**

(ii) A different form of epilepsy has been linked to an abnormality in GABA receptors. Suggest and explain how an abnormality in GABA receptors may result in epilepsy.

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**(3)**

(d) During an epileptic seizure muscular contractions may occur. In which part of the brain would neuronal activity produce muscular contractions of the right leg?

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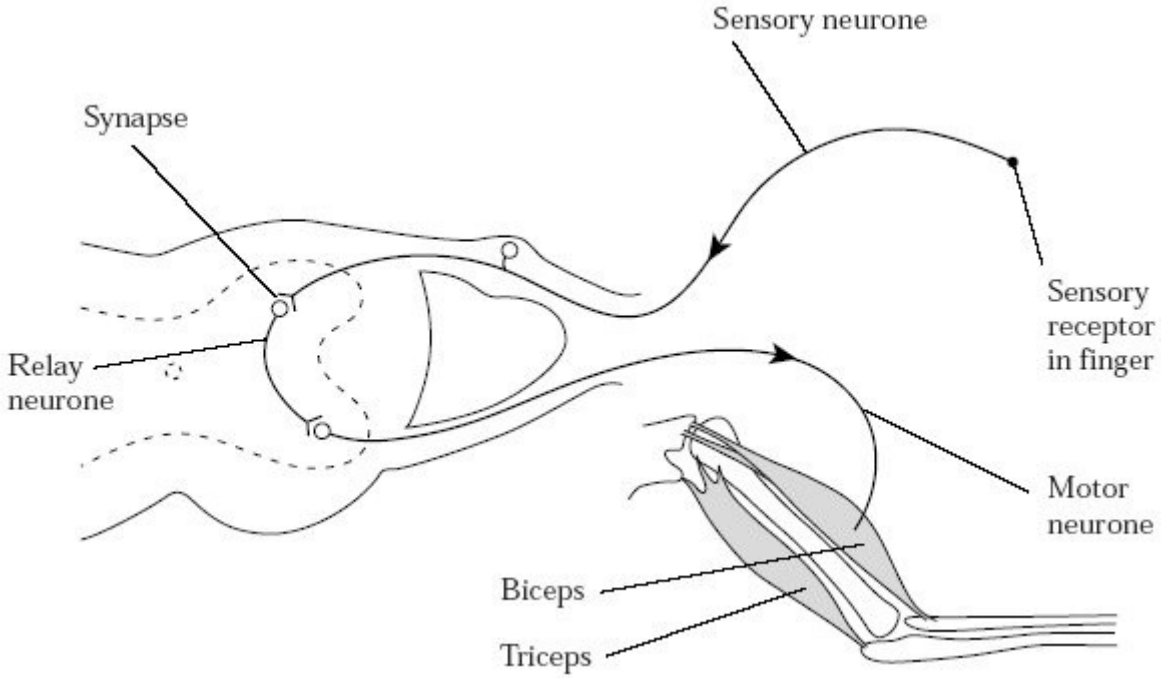
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**(2)**

**(Total 14 marks)**

## Q21.

When a finger accidentally touches a hot object, a reflex action occurs. The biceps muscle contracts, causing the arm to be flexed and the finger is pulled away. The diagram shows the arrangement of the bones in the arm, the muscles used for flexing and straightening the arm and the nervous pathways associated with the contraction of these muscles.




(a) Explain the importance of reflex actions.

**(3)**

(b) (i) Describe the sequence of events which allows information to pass from one neurone to the next neurone across a cholinergic synapse.

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**(6)**

(ii) Give **two** differences between a cholinergic synapse and a neuromuscular junction.

1. _____

_____

2. _____

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**(2)**

**(Total 11 marks)**

## Q22.

This question should be written in continuous prose, where appropriate.

(a) Explain how a resting potential is maintained in a neurone.

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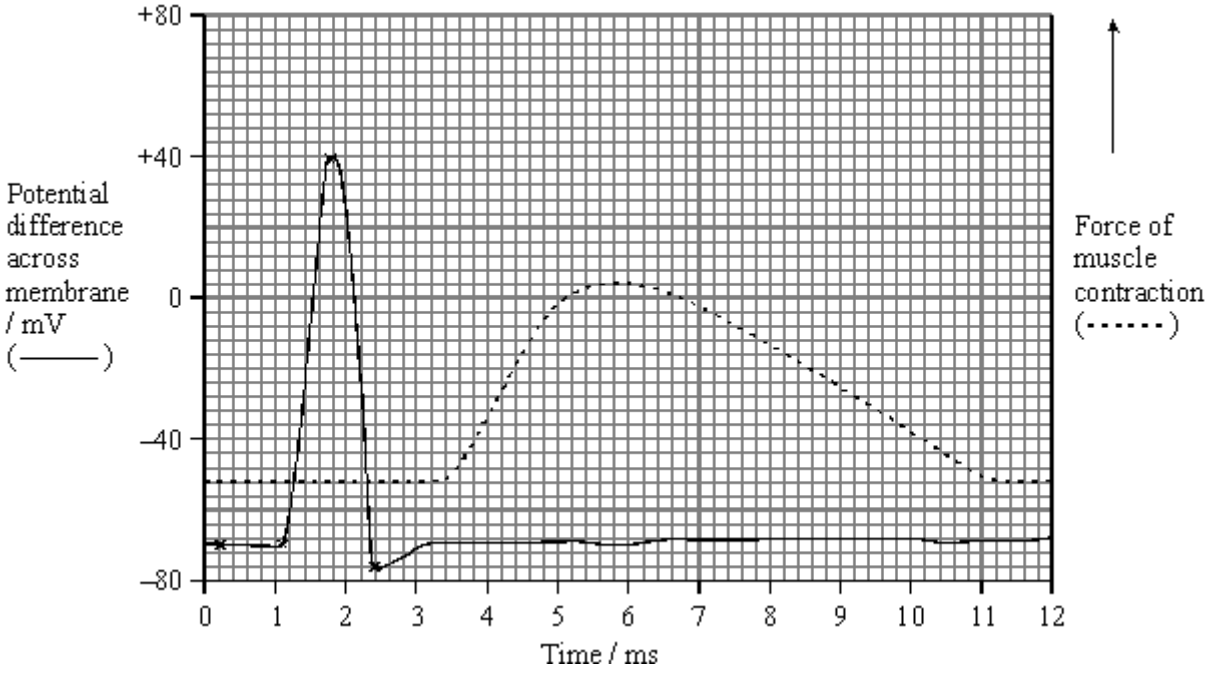
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**(4)**

(b) In an investigation, an impulse was generated in a neurone using electrodes. During transmission along the neurone, an action potential was recorded at one point on the neurone. When the impulse reached the neuromuscular junction, it stimulated a muscle cell to contract. The force generated by the contraction was measured. The results are shown in the graph.

The distance between the point on the neurone where the action potential was measured and the neuromuscular junction was exactly 18 mm.




(i) Use the graph to estimate the time between the maximum depolarisation and the start of contraction by the muscle cell.

Time _____ ms

**(1)**

(ii) Use your answer to part (i) to calculate the speed of transmission along this neurone to the muscle cell. Give your answer in mm per second.

Show your working.

Speed _____ mm $s^{-1}$

**(2)**

(iii) Give **one** reason why the value calculated in part (ii) would be an underestimate of the speed of transmission of an impulse along a neurone.

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**(1)**

Acetylcholine is the neurotransmitter at neuromuscular junctions.

(c) Describe how the release of acetylcholine into a neuromuscular junction causes the cell membrane of a muscle fibre to depolarise.

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**(3)**

(d) Use your knowledge of the processes occurring at a neuromuscular junction to explain each of the following.

(i) The cobra is a very poisonous snake. The molecular structure of cobra toxin is similar to the molecular structure of acetylcholine. The toxin permanently prevents muscle contraction.

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**(2)**

(ii) The insecticide DFP combines with the active site of the enzyme acetylcholinesterase. The muscles stay contracted until the insecticide is lost from the neuromuscular junction.

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**(2)**

**(Total 15 marks)**