NERVOUS COORDINATION

Q1.(a) A myelinated axon conducts impulses faster than a non-myelinated axon. Explain this difference.

Doctors investigated the relationship between myelin in brain tissue and different types of dementia. All types of dementia involve loss of mental ability.

The doctors measured the mean amount of myelin in samples of brain tissue from:

• a control group of 12 people without dementia
• 20 people with vascular dementia (VaD)
• 19 people with Alzheimer’s dementia (AD)
• 31 people with Lewy body dementia (LD).

The doctors’ results are shown in the figure. The vertical bars show standard errors.

(b) The doctors used a statistical test to compare the results for AD and LD. They obtained a value for P of 0.047.

What does this result show about the difference between the means for AD and LD?

Use the words probability and chance in your answer.
A student who read this investigation concluded that there was a relationship between the amount of myelin in a person’s brain and whether or not they had dementia.

Do these data support this conclusion? Give reasons for your answer.

Q2. 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 0.7 ms.
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.

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

Q3. (a) The table shows the membrane potential of an axon at rest and during the different phases of an action potential. Complete the table by writing in each box whether the sodium ion (Na⁺) channels and potassium ion (K⁺) channels are open or closed.

<table>
<thead>
<tr>
<th>Membrane potential/mV</th>
<th>Resting</th>
<th>Starting to depolarise</th>
<th>Repolarising</th>
</tr>
</thead>
<tbody>
<tr>
<td>Na⁺ channels in axon membrane</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>K⁺ channels in axon membrane</td>
<td></td>
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</tbody>
</table>
(b) Describe how the resting potential is established in an axon by the movement of ions across the membrane.

(c) Sodium and potassium ions can only cross the axon membrane through proteins. Explain why.

Q4. The graph shows changes in membrane potential that occur during an action potential. It also shows changes in the permeability of the axon membrane to sodium and potassium ions.

(a) Explain what causes

(i) the change in membrane potential between points A and B,
(ii) the change in membrane potential between points B and C.

(b) When a neurone transmits a series of impulses, its rate of oxygen consumption increases. Explain why.

Q5. The resting potential of a neurone is maintained by the unequal distribution of ions inside and outside the plasma membrane. The diagram shows the plasma membrane of a neurone and the three different proteins that are involved in maintaining the resting potential.

(a) Protein C requires ATP to function. Describe the role of protein C.
(b) (i) Proteins A and B differ from each other. Explain why different proteins are required for the diffusion of different ions through the membrane.

(ii) The plasma membrane of the neurone is more permeable to potassium ions than to sodium ions. Give the evidence from the diagram that supports this observation.

Q6. 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.
(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.

(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.

(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.
(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?

Q7. This question should be written in continuous prose, where appropriate.

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

(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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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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(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.

(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.

(Total 15 marks)

Q8. Different substances are involved in coordinating responses in animals.

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

(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.

.............................................................................................................................................. (2)

Q9. 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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(ii) Explain what causes transmission at a synapse to occur in only one direction.

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(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.

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(Total 8 marks)

Mark Scheme

M1. (a)  1. (In myelinated) action potential / depolarisation only at node(s);

2. (In myelinated, nerve impulse) jumps from node to node / saltatory;

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............................................................................................................................. (4)
3. (In myelinated) action potential / impulse does not travel along whole length; 
   The question is about speed of transmission, not repolarisation or related matters
   Accept converse for non-myelinated

(b) 1. Probability of obtaining this difference by chance; 
   Reject ‘results’ once only
   This statement often split round 2.

2. Is less than 5% / less than 0.05 / less than one in twenty; 
   Accept is 4.7% / 0.047 but reject less than 4.7% / 0.047
   Accept correct greater than 95% / greater than 0.95 arguments

3. Difference is significant; 
   Reject ‘results’ once only

(c) 1. (All) dementia results lower (than control group) / non-dementia result higher;

2. Error bars do not overlap so differences are (possibly) significant; 
   Neutral results
   Accept not due to chance / statistically significant
   In this context, accept references to standard deviation

3. Dementia may be due to other factors / not only due to a lack of myelin; 
   Accept suitable named factor e.g. genetic

4. (Because) big / significant differences in myelin in different dementia; 
   Not just ‘different’

5. Only small sample sizes / only one study / more data required;

M2. (a) (Ion) channel proteins open, sodium in;

Changes membrane potential / makes inside of axon less negative / positive / depolarisation / reaches threshold;

More channels open / positive feedback;
   Accept other phrases for ion channel proteins providing that it is clear that it is something through which ions pass.
   Reject carrier.
   First marking point relates to opening.
   Third point must relate to more (channels) opening.

(b) Potassium channels open;

Potassium out;

Sodium channels close;
   Do not penalise candidate who refers to sodium or potassium.
   Ions are mentioned in question.
   Reject pump
(c) Pump / active transport / transport against concentration gradient;

Of sodium from axon / sodium out / of potassium in;

Do not penalise candidate who refers to sodium or potassium. Ions are mentioned in question

M3. (a) closed open closed;
closed closed open;

(b) active transport / pump of Na⁺ out of axon;
diffusion of K⁺ out of axon / little diffusion of Na⁺ into the axon;

(c) can not pass through phospholipid bilayer;
because water soluble / not lipid soluble / charged / hydrophilic / hydrated;

M4. (a) (i) A to B:
Mark (i) and (ii) as a whole

Sodium channels open / membrane more permeable to sodium (ions);

Max 3 for each section

Sodium ions enter;By diffusion / from high to low concentration;

Allow ‘diffusion’ point ONCE only

Ref. sodium ions have positive charge / cause change from negative to positive potential;

Accept refs to sodium and potassium

(ii) After B:

Sodium channels close;Potassium channels open / membrane more permeable to potassium ions;Potassium ions leave;By diffusion / from high to low concentration (ONCE only);

4 max

(b) (More) respiration;
Reject anaerobic respiration

(More) energy supplied / (more) ATP supplied;
Reject ‘produce’ energy

For active transport of ions / ‘sodium (-potassium) pump’ / pumping out sodium ions / for neurotransmitter synthesis / for vesicle movement;

Accept named e.g.

M5. (a) Transports Na⁺ and K⁺;
By active transport / pump / against concentration gradient;
Restores ion balance after an action potential;
[reject K\(^+\) out and Na\(^+\) in]

(b)  (i) each protein has a specific tertiary structure / shape;
because the ions have different sizes / shape / charge;
[reject receptors binding]

(ii) fewer protein B molecules, which transport sodium ions / more
protein A molecules, which transport potassium ions;

M6.  (a) action potential arrives / depolarisation occurs;
calcium ions enter synaptic knob;
vesicles fuse with membrane;
acetylcholine diffuses (across synaptic cleft);
binds to receptors;

(b) inside becomes more negatively charged / hyperpolarised; stimulation
does not reach threshold level / action potential not produced;
depolarisation does not occur / reduces effect of sodium ions entering;

(c) (i) inhibits enzyme (which breaks down GABA);
more GABA available (to inhibit neurone);

OR

binds to (GABA) receptors;
inhibits neuronal activity / chloride ions enter (neurone);

(ii) receptors have different tertiary / 3D structure / shape not
complementary;
GABA cannot bind; inhibition of neuronal activity does not occur /
chloride ions do not enter;

M7.  (a) membrane relatively impermeable / less permeable to sodium ions / gated channels
are closed / fewer channels;
sodium ions pumped / actively transported out;
by sodium ion carrier / intrinsic proteins;
inside negative compared to outside / 3 sodium ions out for two potassium ions in;
(if sodium mentioned but not in context of ions, negate 1 mark)

(b)  (i) 1.6;

(ii) \(18 \div 1.6 = 11.25\);
multiply by 1000 to convert from ms to s / 11 250;

\[
\frac{\text{distance}}{\text{time}} = \frac{11.25 \times 1000}{1.6}
\]
(correct method = 1 mark, i.e. \(\text{distance} \div \text{time} \times 1000\))
(correct answer based on (b)(i) = 2 marks)
(iii) time for transmission / diffusion across the neuromuscular junction / synapse; time for muscle (fibrils) to contract;  

1 max

(c) movement by diffusion; binding to receptors on (post-synaptic) membrane; causing sodium channels to open / sodium ions to move in to muscle (cell);  

3

(d) (i) toxin binds to / competes for / blocks the acetylcholine receptors; acetylcholine can not depolarise the membrane / the toxin does not cause depolarisation;  

(allow references to generating action potentials instead of depolarisation, do not allow references to impulses in muscles)  

2

(ii) acetylcholinesterase is unable to breakdown acetylcholine; acetylcholine still available to depolarise the membrane / generate action potentials in the membrane;  

2

M8. (a) 1. (Acetylcholine) released from / in presynaptic side;  

2. Receptors in postsynaptic (side) / binds on postsynaptic (side);  

2. Mark for diffusion only awarded in context of unidirectional movement.  

2

(b) (i) 1. Rapid response;  

2. Short duration;  

Specific wording is not important. It is the principles that matter here.  

Points may be made by referring to figures.  

2

M9. (i) Binds to receptor / proteins; and opens Na⁺ channels;  

Na⁺ enter and make membrane potential less negative / depolarised  

2

(ii) (Vesicles containing) neurotransmitter only in presynaptic membrane / neurone; receptor / proteins only in postsynaptic membrane / neurone;  

2

(iii) GABA opens K⁺ and Cl⁻ channels so K⁺ passes out and Cl⁻ passes in;  

Membrane potential more negative / hyperpolarised;  

Requires increased stimulation / must open more Na⁺ channels / allow more Na⁺ to enter;  

To reach threshold;  

4