HELICATE · A-LEVEL BIOLOGY · TOPIC BANK

3.6.2 Nervous coordination

Mark scheme

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TOTAL MARKS	QUESTIONS
61	8

How to use this mark scheme

;	Separates marking points. Each semicolon marks the end of one creditable point, and each point is worth one mark.
;;	Two marks for this answer (used for calculations).
/	Alternative words or phrases that are credited for the same point.
OR	An alternative answer for the same mark.
( )	Words in brackets are not needed to gain the mark.
max	More marking points are listed than marks available. Award up to the number of marks shown.
Accept	An alternative answer that gains credit.
Reject	A wrong answer. It does not gain credit and cancels a correct point it contradicts.
Ignore	Neither credited nor penalised. Mark the rest of the answer.
ECF	Error carried forward: credit correct working that uses an earlier wrong answer.
AO	Assessment objective: AO1 knowledge and understanding; AO2 applying knowledge; AO3 analysing, interpreting and evaluating.

Where an answer is correct but not listed, credit it if it is biologically accurate and answers the question at the depth the marks require. Right + wrong = wrong: a contradiction cancels a correct point.

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Neurones and the resting potential 3.6.2.1

Question	Marking guidance	Mark	Comments
01.1	Contains the nucleus of the neurone: B Provides electrical insulation: C Where depolarisation occurs during saltatory conduction: D Releases neurotransmitter: F;;	**2** (2 × AO1)	4 correct = 2 marks; 2 or 3 correct = 1 mark **Accept** the name of the structure instead of the letter only if it is correct, eg cell body, Schwann cell / myelin (sheath), node of Ranvier, synaptic knob **Reject** more than one letter in a box

Question	Marking guidance	Mark	Comments
01.2	1. Sodium ions are actively transported out **and** potassium ions in OR sodium-potassium pump (produces these concentrations); 2. Membrane is more permeable to potassium ions than to sodium ions OR (most) sodium ion channels are closed; 3. Potassium ions diffuse out (through open channels) down their concentration gradient (140 inside v 4 outside); 4. So there are more positive ions outside than inside OR net loss of positive charge from the axon;	**3 max** (2 × AO1) (1 × AO2)	Reference to ions is required. If ions are mentioned once, allow for all points. Two or three points without any reference to ions = 1 mark max **Accept** Na^+ and K^+ 1. **Accept** 3 sodium ions out and 2 potassium ions in; reject if the numbers are wrong or reversed 1. **Reject** the pump described as diffusion 2. **Accept** impermeable to sodium ions; reject impermeable to both ions 3. **Reject** potassium ions actively transported out

Question	Marking guidance	Mark	Comments
01.3	1. As the concentration (outside) increases, the resting potential becomes less negative/increases/moves towards 0 mV (from −84 to −14 mV); 2. The concentration gradient of potassium ions (across the membrane) is smaller; 3. Fewer potassium ions diffuse out (of the axon) OR more potassium ions remain inside; 4. So less positive charge is lost OR the difference in charge across the membrane is smaller;	**3 max** (2 × AO2) (1 × AO3)	Reference to ions is required for points 2 and 3 1. **Accept** correct use of any pair of values from Figure 2 1. **Accept** resting potential decreases only if clearly meaning its size, eg "becomes smaller in size" **Reject** potassium ions are actively transported out **Ignore** references to the sodium-potassium pump stopping

Question	Marking guidance	Mark	Comments
01.4	(Sodium ion concentration) also affects the resting potential (eg sodium ions diffuse in / changes the sodium ion gradient), so the change is due only to the potassium ion concentration;	**1** (1 × AO3)	**Accept** "it is a control variable" only if linked to its effect on resting potential **Ignore** "fair test" unqualified

Action potentials and the refractory period 3.6.2.1

Question	Marking guidance	Mark	Comments
02.1	Sodium ions diffuse into the axon;	**1** (1 × AO1)	Between P and Q the membrane becomes more permeable to sodium ions, which diffuse in and depolarise the membrane.

Question	Marking guidance	Mark	Comments
02.2	1. Sodium ion channels close OR membrane becomes less permeable to sodium ions; 2. Potassium ion channels open OR membrane becomes more permeable to potassium ions; 3. Potassium ions diffuse out (of the axon) (making the inside negative again); 4. (Potassium ion channels are slow to close, so) too many potassium ions diffuse out, making the potential more negative than the resting potential OR hyperpolarisation (−80 mV);	**2 max** (2 × AO1)	**Accept** Na^+ and K^+ **Accept** voltage-gated channels, but this is not required **Reject** the sodium-potassium pump as the cause **Reject** potassium ions actively transported out **Reject** "messages"/"signals" (penalise once)

Question	Marking guidance	Mark	Comments
02.3	1. An action potential is produced only if (depolarisation reaches) threshold; 2. Stimuli of 0.5 and 1.0 V did not reach threshold, so no action potential was produced; 3. All stimuli of 1.5 V or more produced action potentials of the same size (+35 mV) OR a bigger stimulus did not give a bigger action potential;	**2 max** (1 × AO1) (1 × AO3)	**Max 1** if Table 2 is not used **Accept** impulse for action potential **Ignore** any numerical value given for threshold

Question	Marking guidance	Mark	Comments
02.4	Correct answer for 2 marks: 400 (impulses s^{-1});; Accept for 1 mark: $1 \div 0.0025$ OR $1 \div (2.5 \times 10^{-3})$ **OR** 0.4 (ms not converted to s)	**2** (2 × AO2)	**Accept** 400 Hz **Accept** 24 000 (impulses) per minute for 2 marks only if the unit is changed

Question	Marking guidance	Mark	Comments
02.5	1. (No new action potential can be produced during the refractory period, so) action potentials are discrete/separate OR do not overlap/merge; 2. Limits the (maximum) frequency of impulses OR sets a minimum time between impulses; 3. Action potentials pass in one direction only (along the axon) OR cannot pass back into the region just depolarised;	**2 max** (2 × AO1)	3. **Credit** as extra detail; not required for 2 marks **Ignore** references to absolute or relative refractory periods **Reject** refraction period; reject rest period / lag time **Reject** "messages"/"signals" (penalise once)

Speed of conduction 3.6.2.1

Question	Marking guidance	Mark	Comments
03.1	Correct answer for 2 marks: 25 (m s^{-1});; Accept for 1 mark, one conversion error: 0.025 (distance converted to m but time not converted) OR 25 000 (time converted to s but distance not converted) **OR** 0.040 ÷ 0.0016	**2** (2 × AO2)	Working: 40 mm = 0.040 m; 1.6 ms = 0.0016 s; 0.040 ÷ 0.0016 = 25 **Accept** 2.5 × 10^{1}

Question	Marking guidance	Mark	Comments
03.2	1. The time from S includes the time for the stimulus to depolarise the membrane to threshold OR to produce the action potential (which is not conduction); 2. So the speed would be underestimated OR only the time for conduction along a known distance is measured; 3. The exact point where the action potential starts (near S) is uncertain, so the distance would be uncertain;	**2 max** (2 × AO3)	**Ignore** "to make it more accurate" unqualified **Ignore** references to reaction time

Question	Marking guidance	Mark	Comments
03.3	Answer (1 mark): 0.84; Unit (1 mark): m s^{-1} $°C^{-1}$;	**2** (2 × AO2)	Working: (32 − 11) ÷ (30 − 5) = 0.84 **Accept** readings of 10.5–11.5 and 31.5–32.5, giving answers from 0.80 to 0.88 **Accept** 0.8 Unit: accept m/s/°C, m s^{-1} per °C, metres per second per degree; mark the unit independently of the value Unit: reject m s^{-1} alone

Question	Marking guidance	Mark	Comments
03.4	1. (At higher temperature, ions have) more kinetic energy; 2. (Sodium/potassium) ions diffuse faster (through ion channels); 3. So the next part of the axon/next node depolarises/reaches threshold sooner;	**2 max** (2 × AO2)	**Ignore** a description of the trend alone **Ignore** references to the sodium-potassium pump working faster **Reject** thermal insulation **Reject** enzyme/active site applied to ion channels or receptors

Question	Marking guidance	Mark	Comments
03.5	(Channel/carrier/pump) proteins in the membrane are denatured (so ions cannot move through the membrane);	**1** (1 × AO2)	**Accept** tertiary structure of channel proteins / sodium-potassium pump changed **Accept** membrane damaged / phospholipids too fluid, so ions leak across it **Ignore** enzymes denatured unqualified

Question	Marking guidance	Mark	Comments
04.1	125 (times);	**1** (1 × AO2)	Working: 500 ÷ 4 = 125

Question	Marking guidance	Mark	Comments
04.2	1. (Cat axon is myelinated;) myelin provides (electrical) insulation OR ions cannot pass through the myelin; 2. Saltatory conduction OR depolarisation/action potentials occur only at the nodes (of Ranvier); 3. (Squid axon is non-myelinated, so) depolarisation occurs along the whole length of the axon; 4. The squid axon's much larger diameter increases its speed OR a wider axon has less resistance to the flow of ions / less leakage of ions; 5. Cat axon was measured at a higher temperature (37 °C v 18 °C), so ions diffuse faster OR depolarisation (at each node) is faster; 6. The cat axon is 125 times narrower but almost as fast, so myelination/saltatory conduction (and the higher temperature) make up for its smaller diameter;	**4 max** (2 × AO1) (1 × AO2) (1 × AO3)	**Max 3** if Table 3 is not used 1. **Reject** thermal insulation 2. "Impulses jump from node to node" alone is not enough; depolarisation/action potentials at the nodes are needed 3. **Accept** action potentials for depolarisation **Reject** "messages"/"signals" (penalise once)

Question	Marking guidance	Mark	Comments
04.3	1. Speeds were measured at different temperatures (37 °C v 18 °C), which affect speed; 2. Diameters also differ, so more than one variable changes; 3. Axons are from different species OR other differences between the axons/neurones may affect speed; 4. Only one axon of each type OR no repeats/means/ranges given;	**3 max** (3 × AO3)	1. **Accept** the myelinated axons would be slower at 18 °C / part of the difference may be due to temperature, but do not credit a temperature reason twice **Ignore** "fair test" unqualified

Synaptic transmission 3.6.2.2

Question	Marking guidance	Mark	Comments
05.1	Calcium ion channels: Presynaptic membrane Acetylcholine receptors: Postsynaptic membrane;	**1** (1 × AO1)	

Question	Marking guidance	Mark	Comments
05.2	1. Calcium ion channels open and calcium ions enter the synaptic knob/presynaptic neurone; 2. (Calcium ions cause) synaptic vesicles to move to/fuse with the presynaptic membrane and release acetylcholine; 3. Acetylcholine diffuses across the (synaptic) cleft; 4. Acetylcholine attaches/binds to receptors on the postsynaptic membrane; 5. Sodium ions enter (the postsynaptic neurone), causing depolarisation; 6. Only the presynaptic neurone/knob has vesicles/releases acetylcholine; 7. Only the postsynaptic membrane has (acetylcholine) receptors OR no receptors on the presynaptic membrane;	**5 max** (5 × AO1)	**Max 4** if neither point 6 nor point 7 is given (these explain why the student is wrong) **Accept** ACh; accept Ca^{2+} and Na^{+} 1. **Reject** "presynaptic membrane" alone for where calcium ions enter 2. **Reject** vesicles cross the cleft / vesicles released into the cleft 4. **Reject** active site for receptor 5. "Sodium ion channels open" alone is not enough; sodium ions must enter 6. **Ignore** "transmitter" without "neuro-" **Ignore** references to refractory periods or concentration gradients for unidirectionality **Reject** "messages"/"signals" (penalise once)

Question	Marking guidance	Mark	Comments
05.3	1. Impulses in quick succession release more acetylcholine (into the cleft) OR acetylcholine builds up; 2. More sodium ions enter (neurone X) OR the depolarisations add together; 3. (So the membrane potential) reaches threshold (−55 mV) OR in experiment 1 the depolarisation (−62 mV) is below threshold (−55 mV); 4. Temporal summation;	**2 max** (2 × AO2)	**Max 1** if there is no reference to what builds up or adds together (acetylcholine, sodium ions or depolarisation) 3. **Accept** "enough to cause depolarisation/an action potential" for reaching threshold **Reject** spatial summation

Question	Marking guidance	Mark	Comments
05.4	Spatial (summation);	**1** (1 × AO2)	**Reject** temporal

Question	Marking guidance	Mark	Comments
05.5	1. Neurone C causes hyperpolarisation OR makes the inside of X more negative (−76 mV in experiment 4); 2. So more sodium ions must enter (X) to reach threshold OR sodium ions entering are prevented from causing enough depolarisation; 3. (The effects of A, B and C add together, so) X reaches only −59 mV, which is below threshold (−55 mV); 4. A and B together produced an action potential in experiment 3, so C cancels part of their depolarisation;	**3 max** (1 × AO2) (2 × AO3)	**Accept** "potential below resting potential" or "potential difference greater" for point 1; reject "reduces potential difference" **Accept** chloride ions entering or potassium ions leaving as the cause of hyperpolarisation, but neither is required **Reject** sodium ions leave

Neuromuscular junctions and drugs 3.6.2.2

Question	Marking guidance	Mark	Comments
06	1. Neuromuscular junction is always excitatory, but a synapse may be excitatory or inhibitory; 2. At a neuromuscular junction the postsynaptic cell is a muscle fibre/effector (acetylcholine binds to receptors on the sarcolemma) and the impulse ends there, but at a synapse it is another neurone (in which a new action potential may be produced); 3. Neuromuscular junction involves only motor neurones, but synapses involve sensory, relay or motor neurones; 4. At a neuromuscular junction each impulse causes an action potential in the muscle fibre (no summation needed), but at a synapse summation may be needed to reach threshold;	**2 max** (2 × AO1)	Each point must compare both junctions; one side only = no mark **Accept** ACh 2. Any one of these ideas gains the mark: muscle fibre/sarcolemma v neurone membrane, or impulse ends at the effector v new action potential in another neurone. Do not credit point 2 twice 2. **Accept** postsynaptic membrane of a muscle fibre for sarcolemma; reject "muscle" alone

Question	Marking guidance	Mark	Comments
07.1	1. Without drug Y the size of the depolarisation stays (almost) constant OR falls only slightly (to 95%); 2. With drug Y the depolarisation gets smaller with time (to 24% after 10 s); 3. Choline is not taken back into the synaptic knob/presynaptic neurone, so less acetylcholine is (re)synthesised; 4. Acetylcholine stored in vesicles is used up by repeated stimulation OR fewer vesicles/less acetylcholine released per impulse; 5. Less acetylcholine diffuses across the cleft and binds to receptors on the sarcolemma/postsynaptic membrane; 6. Fewer sodium ions enter (the muscle fibre), so the depolarisation is smaller; 7. After about 6–7 s the depolarisation is below 40%/threshold, so no action potential is produced and the muscle fibre stops contracting;	**6 max** (3 × AO2) (3 × AO3)	**Max 4** if no data from Figure 6 are used 4. **Accept** the first depolarisations are normal because acetylcholine was already stored in vesicles 5. **Reject** active site for receptor 6. "Sodium ion channels do not open" alone is not enough; refer to fewer sodium ions entering 7. Plotted values: 42% at 6 s and 36% at 7 s; accept any time from 6 to 7 s 7. **Accept** "does not reach threshold" without a time **Accept** ACh **Reject** "messages"/"signals" (penalise once) **Reject** calcium ions released from the sarcoplasmic reticulum as an effect of drug Y unless linked to fewer action potentials

Question	Marking guidance	Mark	Comments
07.2	1. The size of the first depolarisation (in mV) may differ between muscle fibres/preparations OR depends on where the electrode is placed; 2. A percentage shows the change/decrease with time and allows comparison with and without drug Y;	**2** (2 × AO3)	**Ignore** "easier to compare" unless the reason for the comparison is given

Question	Marking guidance	Mark	Comments
08.1	Fewer sodium ions enter the postsynaptic neurone;	**1** (1 × AO2)	Less acetylcholine binds to receptors, so fewer receptor sodium ion channels open.

Question	Marking guidance	Mark	Comments
08.2	1. Greater/longer hyperpolarisation OR inside of the postsynaptic neurone is more negative (for longer); 2. More sodium ions must enter to reach threshold OR more excitatory input/summation is needed to reach threshold; 3. Fewer action potentials (in postsynaptic neurones) OR lower frequency of impulses; 4. So fewer neurones are stimulated OR (high-frequency) activity spreads to fewer neurones;	**3 max** (3 × AO2)	**Accept** "potential further below resting potential" for point 1; reject "reduces potential difference" **Accept** chloride ions entering, but this is not required **Reject** drug V acting as GABA / binding to the active site **Reject** "messages"/"signals" (penalise once)

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