1.6 Organisms Respond to Changes in their Environments: 1-hour Pack

AQA 7402 · Calculator allowed · about 60 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 Required practical. A simple ruler-drop test was used to measure a person's reaction time. One person held a ruler vertically with the zero mark between the thumb and forefinger of a second person, who was looking at the ruler. The first person released the ruler without warning, and the second person caught it as quickly as possible. The distance the ruler fell before being caught was recorded.

(a) Describe how this test should be carried out to obtain a reliable estimate of a person's mean reaction time. **(3)**

(b) In one trial, the ruler fell 18.0 cm before being caught. Using $s = 1/2 \times g \times t^2$ (where $g = 9.81\ m/s^2$), calculate the person's reaction time in milliseconds. **(4)**

(c) Explain one variable that should be controlled when comparing reaction times between different people, and suggest one way to improve the reliability of the comparison. **(2)**

(d) The reaction time measured in this test includes the time taken for sensory processing, decision-making in the brain, and the motor response, as well as synaptic delays. Explain why this measured reaction time is much longer than the time taken for a single action potential to cross one synapse. **(2)**

(Total for Question 1 is 11 marks)

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2 Thermoregulation in mammals is controlled by the thermoregulatory centre in the hypothalamus, which coordinates responses to both a rise and a fall in core body temperature.

(a) State the two types of receptor, and their locations, that provide the thermoregulatory centre with information about temperature. **(2)**

(b) Explain how vasodilation of arterioles supplying the skin capillaries helps to lower body temperature when core temperature rises above normal. **(3)**

(c) Explain how shivering helps to raise body temperature when core temperature falls below normal. **(2)**

(d) Explain why thermoregulation is described as an example of negative feedback control involving effectors that can produce opposite responses (antagonistic effectors). **(1)**

(Total for Question 2 is 8 marks)

3 Synaptic transmission at a cholinergic synapse can be modified by the number and pattern of impulses arriving at the presynaptic neurone(s).

(a) Explain why transmission across a cholinergic synapse can only occur in one direction (from the presynaptic to the postsynaptic neurone). **(2)**

(b) Explain the difference between spatial summation and temporal summation, and how each can help a postsynaptic neurone reach the threshold needed to generate an action potential. **(3)**

(Total for Question 3 is 5 marks)

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4 Heart rate is controlled by the cardiovascular (cardiac) centre in the medulla oblongata, which receives information from receptors in the walls of the aorta and carotid arteries and sends impulses to the heart via the autonomic nervous system.

(a) Explain how baroreceptors help to reduce heart rate when blood pressure rises above normal. **(4)**

(b) Explain how chemoreceptors help to increase heart rate in response to a fall in blood pH (caused by a rise in dissolved carbon dioxide). **(4)**

(c) A person at rest has a heart rate of 68 beats per minute and a stroke volume of 72 cm^3. Using cardiac output (cm^3/min) = heart rate x stroke volume, calculate their cardiac output in dm^3 per minute. **(3)**

(Total for Question 4 is 11 marks)

5 Animals coordinate responses to changes in their external environment using both the nervous system and the hormonal (endocrine) system. Compare and contrast nervous and hormonal communication as means of coordinating a response to a change in the external environment.

(Total for Question 5 is 6 marks)

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6 The table shows the membrane potential of an axon recorded every 0.5 milliseconds during a single nerve impulse.

Time (ms): 0.0 0.5 1.0 1.5 2.0 2.5 3.0 3.5
Membrane potential (mV): -70 -70 -20 +40 +30 -60 -80 -70

Time (ms)	Membrane potential (mV)
0.0	-70
0.5	-70
1.0	-20
1.5	+40
2.0	+30
2.5	-60
3.0	-80
3.5	-70

(a) Using the data, state the resting potential of the axon and identify the time interval in which depolarisation begins. **(2)**

(b) Explain the ionic basis of the rising phase (depolarisation) and the falling phase (repolarisation) of the action potential shown in the table. **(4)**

(c) Explain why the membrane potential becomes more negative than the resting potential at t = 3.0 ms (hyperpolarisation), and state the importance of the refractory period that follows an action potential. **(3)**

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(d) The absolute refractory period of this axon is 1 millisecond. Calculate the maximum theoretical frequency, in Hz, at which action potentials could be generated. **(2)**

(Total for Question 6 is 11 marks)

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Mark scheme · 1.6 Organisms Respond to Changes in their Environments: 1-hour Pack

Question 1

(a) repeat the test several times (e.g. at least 5-10 times) for each person **B1**

(a) discard anticipatory catches (e.g. where the person appears to guess/close their hand before release) and use random, unpredictable time intervals between repeats **B1**

(a) calculate the mean distance fallen (or mean reaction time) from the repeats, to reduce the effect of anomalous results/random variation **B1**

(a) Answer: Repeat the drop several times per person using random time intervals so the catch cannot be anticipated, discard any obvious anticipatory catches, and calculate a mean value from the repeats.

(b) rearranges correctly to $t = \sqrt{2s/g}$ **M1**

(b) correctly substitutes s = 0.180 m: $t = \sqrt{(2 \times 0.180)/9.81}$ **M1**

(b) t = 0.192 s (awrt 0.19 s) **A1**

(b) converts to 192 ms (awrt 190-193 ms) **A1**

(b) Answer: 192 ms (0.192 s)

(c) control a variable such as the hand/finger position used to catch, whether the dominant hand is used, time of day, or level of alertness/caffeine intake, with a reason why it affects reaction time (any valid confounding variable with reason) **B1**

(c) suggest a way to improve reliability, e.g. increasing the number of repeats per person and/or testing multiple people to calculate a mean, to reduce the effect of random variation between individual trials **B1**

(c) Answer: For example, the hand used to catch should be the same for every person tested (dominant hand affects reaction time); reliability can be improved by increasing the number of repeats per person and averaging the results.

(d) the measured reaction time involves impulses passing along several neurones (sensory, relay/interneurones in the brain, and motor) and crossing more than one synapse, each of which adds a synaptic delay **B1**

(d) it also includes the time needed for processing/decision-making in the brain and for the muscle to respond and physically move the hand, not just the transmission across a single synapse **B1**

(d) Answer: The overall reaction time includes conduction along several neurones, several synaptic delays (not just one), processing time in the brain, and the time for the muscle to contract and move the hand, so it is much longer than a single synaptic crossing time.

Question 2

(a) thermoreceptors in the skin, which detect the temperature of the external environment/skin surface oe **B1**

(a) thermoreceptors within the hypothalamus itself, which detect the temperature of the blood flowing through it (core body temperature) oe **B1**

(a) Answer: Thermoreceptors in the skin (detecting external/skin temperature) and thermoreceptors in the hypothalamus itself (detecting core blood temperature).

(b) arterioles supplying the skin capillary network dilate (widen), allowing more blood to flow close to the skin surface, into the capillary network oe **B1**

(b) this increases the flow of warm blood near the body surface oe **B1**

(b) increasing the transfer of heat from the blood to the environment (by radiation/convection/conduction), cooling the blood and lowering body temperature oe **B1**

(b) Answer: Vasodilation lets more warm blood flow through capillaries near the skin surface, increasing heat loss to the environment by radiation and convection, cooling the blood and lowering body temperature.

(c) shivering involves rapid, involuntary contraction and relaxation of skeletal muscles oe **B1**

(c) these contractions require respiration, which releases heat as a by-product, warming the body oe **B1**

(c) Answer: Shivering causes rapid involuntary muscle contractions; the increased respiration this requires releases heat as a by-product, warming the body.

(d) a rise in temperature triggers heat-losing responses (e.g. vasodilation, sweating) while a fall in temperature triggers heat-generating/conserving responses (e.g. shivering, vasoconstriction) - each response counteracts the original deviation, and the two sets of effectors act in opposite directions to keep temperature within a narrow range oe **B1**

(d) Answer: Rising temperature triggers heat-losing responses and falling temperature triggers heat-generating responses; these opposite (antagonistic) effector actions each counteract the original change, keeping body temperature within a narrow range around the set point.

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Question 3

(a) only the presynaptic neurone contains synaptic vesicles of neurotransmitter (acetylcholine) that can be released **B1**

(a) only the postsynaptic membrane has the specific receptors for the neurotransmitter, to which acetylcholine can bind and open ion channels **B1**

(a) Answer: Only the presynaptic neurone has vesicles able to release acetylcholine, and only the postsynaptic membrane has receptors for it, so signals can only pass from the presynaptic to the postsynaptic neurone.

(b) spatial summation: several different presynaptic neurones each release a small amount of neurotransmitter onto the same postsynaptic neurone at the same time, so their combined (summed) effect on depolarisation may reach threshold **B1**

(b) temporal summation: a single presynaptic neurone releases neurotransmitter repeatedly, in quick succession, so the depolarisations combine (summate) before they fade, reaching threshold **B1**

(b) in both cases, no single release of neurotransmitter is enough on its own to reach threshold, but the combined/summed depolarisations can reach threshold and trigger an action potential (oe) **B1**

(b) Answer: Spatial summation combines small depolarisations from several different presynaptic neurones acting at the same time; temporal summation combines repeated depolarisations from the same presynaptic neurone in quick succession. In both cases, individually sub-threshold signals combine to reach the threshold needed for an action potential.

Question 4

(a) baroreceptors detect the increased stretching of the artery wall caused by the rise in blood pressure **B1**

(a) they send an increased frequency of impulses along sensory neurones to the cardiovascular centre in the medulla oblongata **B1**

(a) the medulla sends an increased frequency of impulses along parasympathetic (vagus) neurones to the sinoatrial node (SAN), and a decreased frequency of impulses along sympathetic neurones **B1**

(a) acetylcholine released at the SAN reduces its rate of firing, decreasing heart rate back towards normal **B1**

(a) Answer: Baroreceptors detect the extra stretch from raised blood pressure and send more impulses to the medulla, which increases parasympathetic (vagus) and decreases sympathetic output to the SAN, releasing more acetylcholine and slowing heart rate back to normal.

(b) chemoreceptors in the aorta, carotid arteries and medulla detect the fall in blood pH (rise in CO_2 concentration) **B1**

(b) they send an increased frequency of impulses along sensory neurones to the cardiovascular centre in the medulla oblongata **B1**

(b) the medulla sends an increased frequency of impulses along sympathetic neurones to the SAN, and a decreased frequency along parasympathetic (vagus) neurones **B1**

(b) noradrenaline released at the SAN increases its rate of firing, increasing heart rate, which increases blood flow to the lungs and removal of carbon dioxide (oe) **B1**

(b) Answer: Chemoreceptors detect the fall in pH/rise in CO_2 and send more impulses to the medulla, which increases sympathetic and decreases parasympathetic output to the SAN, releasing noradrenaline and increasing heart rate to remove CO_2 faster.

(c) correct substitution: 68 x 72 **M1**

(c) 4896 cm^3/min **A1**

(c) 4.9 dm^3/min (awrt 4.9, correct conversion of cm^3 to dm^3 by dividing by 1000) **A1**

(c) Answer: 4.9 dm^3 per minute (4896 cm^3/min)

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Question 5

Level 3 The answer gives a well-balanced, detailed comparison covering both similarities and differences between nervous and hormonal communication, using correct scientific terminology and, where appropriate, an example to illustrate the points made. **5-6**

Level 2 The answer identifies several valid differences and/or similarities between nervous and hormonal communication, with reasonable use of terminology, but the comparison may be less detailed, one-sided, or lack an illustrative example. **3-4**

Level 1 The answer makes one or two simple, isolated correct points about nervous or hormonal communication, with little genuine comparison between the two. **1-2**

Level 0 No relevant content, or the response does not address the question. **0**

Indicative content:

- Nervous communication uses electrical impulses (action potentials) travelling along neurones; hormonal communication uses chemical messengers (hormones) carried in the blood
- Nervous transmission is much faster than hormonal transmission, which relies on the relatively slow circulation of blood
- Nervous responses tend to be short-lived/rapidly reversed once the stimulus stops; hormonal effects tend to be longer-lasting
- Nervous signals act on a specific, localised target (the effector connected by the neurone via a synapse); hormones are carried throughout the body in the blood and can affect many different target cells/organs that have the appropriate receptors
- Nervous communication produces a precise, localised response; hormonal communication can produce a widespread, generalised response affecting many organs simultaneously
- Both systems ultimately rely on a receptor/target cell having specific receptor molecules to detect the signal (electrical or chemical), and are used together in many coordinated responses
- A valid example may be used, such as detecting a sudden loud noise (nervous, rapid, localised reflex) compared with the release of adrenaline in response to a threat (hormonal, slower onset but widespread and longer-lasting effects)

Question 6

(a) resting potential = -70 mV **B1**

(a) depolarisation begins after 0.5 ms and by 1.0 ms (accept 'between 0.5 and 1.0 ms'); the exact onset cannot be determined from the sampled readings **B1**

(a) Answer: Resting potential = -70 mV; depolarisation begins after 0.5 ms and by 1.0 ms. The exact onset is undetermined.

(b) a stimulus causes some sodium channels to open; if depolarisation reaches the threshold, voltage-gated sodium channels open **B1**

(b) sodium ions diffuse rapidly into the axon down their electrochemical gradient, causing rapid depolarisation and reversing the potential (inside becomes positive, e.g. reaching +40 mV) **B1**

(b) at the peak, sodium channels close (become inactivated) and voltage-gated potassium channels open **B1**

(b) potassium ions diffuse out of the axon down their concentration gradient, removing positive charge from inside and restoring a negative internal potential (repolarisation) **B1**

(b) Answer: Depolarisation: voltage-gated sodium channels open once threshold is reached, sodium ions flood in, reversing the membrane potential. Repolarisation: sodium channels close, potassium channels open, potassium ions diffuse out, restoring the negative interior.

(c) potassium channels are slower to close than they were to open, so potassium ions continue to diffuse out after the membrane has returned to -70 mV, causing a brief overshoot to a more negative potential (e.g. -80 mV) **B1**

(c) during the refractory period, sodium channels are inactivated/cannot reopen immediately, so a new action potential cannot be generated **B1**

(c) this ensures action potentials only travel in one direction (away from the previous site of depolarisation) and are discrete, separate impulses, which also limits the maximum frequency at which impulses can be generated (oe) **B1**

(c) Answer: Potassium channels stay open slightly too long, so more K^+ leaves than needed, causing a brief hyperpolarisation below resting potential. The refractory period that follows (during which sodium channels cannot reopen) ensures impulses travel in one direction only and are transmitted as discrete impulses, limiting the maximum impulse frequency.

(d) correct method: f = 1/T, using T = 1 ms = 0.001 s **M1**

(d) 1000 Hz (cao) **A1**

(d) Answer: 1000 Hz

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