1.12 Biology: Homeostasis and Response: 1-hour Pack

AQA 7402 · Calculator allowed · about 60 minutes

Total Marks

Name: _____ Date: ____ / ____ / _____

Answer ALL questions. Show all your working.

1 Antidiuretic hormone (ADH) controls the permeability of the collecting duct to water, allowing the kidney to regulate the water potential of the blood.

(a) Explain the role of ADH in regulating blood water potential when a person becomes dehydrated, referring to osmoreceptors, the pituitary gland and aquaporins. **(5)**

(b) Predict and explain what would happen to ADH secretion and urine concentration if a person drank a large volume of water. **(3)**

(c) The kidneys produce approximately 180 dm3 of glomerular filtrate per day. A healthy person excretes 1.5 dm3 of urine per day. Calculate the percentage of the filtrate that is reabsorbed back into the blood. Give your answer to 3 significant figures. **(2)**

(d) A patient with a rare condition affecting ADH receptors in the collecting duct excretes an unusually large volume of dilute urine, even when dehydrated. Suggest and explain the likely effect of this condition on the volume of filtrate reabsorbed, compared with the healthy value calculated in (c). **(2)**

(Total for Question 1 is 12 marks)

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2 Required practical. A group of students dissected a fresh sheep kidney (obtained from a butcher) to observe its internal structure, then photographed a longitudinal section next to a mm scale for later measurement and analysis.

(a) State two safety precautions that should be taken when dissecting a fresh mammalian kidney. **(2)**

(b) Explain why the kidney should be cut longitudinally (rather than transversely) to see the cortex, medulla and pelvis clearly in a single section. **(2)**

(c) Identify the three main regions visible in a longitudinal section of the kidney, and state one function associated with each. **(6)**

(d) The photograph of the dissected kidney was printed at a magnification of x2.5. On the photograph, the width of the cortex measured 20 mm. Calculate the actual width of the cortex, in mm. **(2)**

(e) The whole kidney's actual length was measured directly with a ruler as 90 mm. On the same (x2.5) photograph, this length measured 220 mm. Calculate the percentage error between the expected photograph length (based on the actual length and the stated magnification) and the measured photograph length. Give your answer to 3 significant figures. **(3)**

(f) Suggest one reason why the measured photograph length might differ from the expected length, and suggest two improvements to the method that could reduce the error in this measurement. **(3)**

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(g) The students noted that individual glomeruli could not be seen with the naked eye during the dissection. Suggest an appropriate technique, in addition to gross dissection, that could be used to observe the detailed structure of a single glomerulus and Bowman's capsule, and explain why gross dissection alone is insufficient for this purpose. **(3)**

(h) Explain why the kidney tissue used for dissection should be as fresh as possible, state one appropriate storage method that could be used if immediate dissection is not possible, and explain why preserving the kidney in a fixative such as formalin would be less suitable for taking measurements. **(3)**

(i) Suggest why measuring the same structure (e.g. cortex width) on three different kidneys, rather than on just one, would improve the reliability of any conclusions drawn about typical kidney dimensions. **(2)**

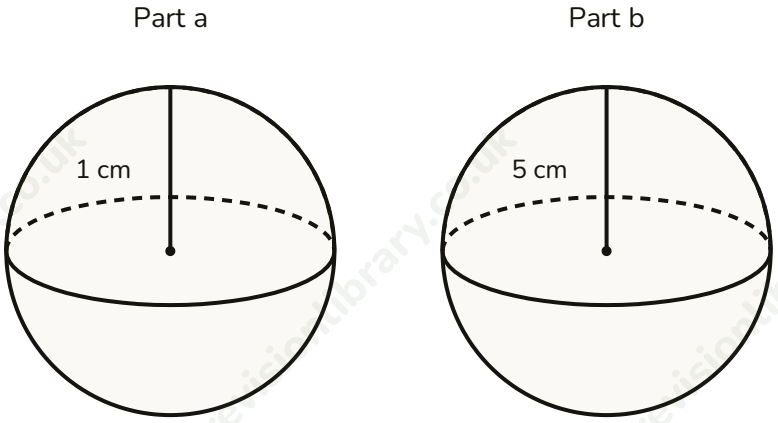
(Total for Question 2 is 26 marks)

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3 Small mammals have a much larger surface area to volume (SA:V) ratio than large mammals, which affects the rate of heat loss and the thermoregulatory demands placed on each animal.

Diagram NOT accurately drawn

The drawings are not drawn to a common scale.



(a) Using the formulae surface area = $4 \times \pi \times r^2$ and volume = $4/3 \times \pi \times r^3$, calculate the surface area to volume (SA:V) ratio of a sphere of radius 1 cm. Give your answer in cm^{-1}, to 3 significant figures. **(2)**

(b) Calculate the SA:V ratio of a sphere of radius 5 cm, to 3 significant figures, and state how the SA:V ratio changes as the radius (size) of a sphere increases. **(2)**

(c) Using your answers to (a) and (b), explain why small mammals (modelled by the sphere of radius 1 cm) generally lose heat more rapidly, relative to their body mass, than large mammals (modelled by the sphere of radius 5 cm). Suggest one adaptation that helps small mammals to reduce this heat loss. **(3)**

(d) A small mammal has a mass of 25 g and a large mammal has a mass of 4000 g. Both generate heat at a rate of 12 J per gram of body mass per hour. Both maintain a constant body temperature at thermal equilibrium, so heat loss equals heat generation. Calculate the total rate of heat generation, in J per hour, for each mammal, and compare the required heat loss per gram of body mass. **(3)**

(Total for Question 3 is 10 marks)

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Mark scheme · 1.12 Biology: Homeostasis and Response: 1-hour Pack

Question 1

(a) osmoreceptor cells in the hypothalamus detect a decrease in the water potential of the blood (the blood becomes more concentrated) **B1**

(a) this stimulates the posterior pituitary gland to release (more) antidiuretic hormone (ADH) into the blood **B1**

(a) ADH binds to (glycoprotein) receptors on the cell-surface membrane of the cells lining the collecting duct (and distal convoluted tubule) **B1**

(a) causing more aquaporin (water channel) proteins to be inserted into the cell-surface membrane, increasing the permeability of the tubule wall to water **B1**

(a) more water is reabsorbed from the filtrate back into the blood by osmosis, producing a smaller volume of more concentrated urine, and restoring blood water potential towards normal (negative feedback) **B1**

(a) Answer: Osmoreceptors detect low blood water potential and stimulate the posterior pituitary to release more ADH; ADH increases aquaporin insertion in the collecting duct, increasing water reabsorption and restoring blood water potential, producing concentrated urine.

(b) drinking a large volume of water increases the water potential of the blood (dilutes the blood) **M1**

(b) this is detected by osmoreceptors in the hypothalamus, which reduces (inhibits) the secretion of ADH from the posterior pituitary gland **M1**

(b) fewer aquaporins are present in the collecting duct membrane, so less water is reabsorbed, producing a larger volume of more dilute urine (oe) **A1**

(b) Answer: ADH secretion decreases because blood water potential rises; fewer aquaporins are inserted in the collecting duct, so less water is reabsorbed, producing a large volume of dilute urine.

(c) volume reabsorbed = 180 - 1.5 = 178.5 (dm3); percentage = (178.5 / 180) x 100 **M1**

(c) 99.2% (awrt 99.2, cao) **A1**

(c) Answer: 99.2%

(d) if the collecting duct cells cannot respond to ADH (unresponsive/faulty receptors), aquaporins are not inserted into the membrane even when ADH is released, so the collecting duct remains relatively impermeable to water **M1**

(d) (much) less water is reabsorbed than the healthy value (less than 178.5 dm3 per day), so a larger volume of filtrate remains in the tubule and is excreted as dilute urine, regardless of hydration status (oe) **A1**

(d) Answer: Far less water would be reabsorbed than the healthy 178.5 dm3 per day, because the collecting duct cannot respond to ADH by inserting aquaporins, so a much larger volume of dilute urine is produced even when dehydrated.

Question 2

(a) wear (disposable) gloves to avoid direct contact with blood/bodily fluids (biological hazard) (oe) **B1**

(a) use a sharp scalpel/dissecting instruments carefully, cutting away from the body and on a dissecting board/mat, and wash hands thoroughly afterwards, and/or dispose of animal tissue according to appropriate biological waste procedures (any two distinct valid precautions) **B1**

(a) Answer: For example: wear disposable gloves when handling the kidney, and use a sharp scalpel carefully on a dissecting board, washing hands thoroughly afterwards.

(b) a longitudinal section cuts along the length of the kidney, from the outer curved surface through the hilum to the opposite side, exposing all three regions (cortex, medulla, pelvis) in one continuous section **B1**

(b) a transverse section (cut across the width) would only show the cortex and medulla as rings/segments, without clearly showing the pelvis and its connection to the ureter (oe) **B1**

(b) Answer: A longitudinal cut runs the full length of the kidney through the hilum, showing the cortex, medulla and pelvis together; a transverse cut would not show the pelvis and ureter connection clearly.

(c) cortex identified correctly (outer region) **B1**

(c) cortex function - contains the glomeruli and Bowman's capsules, the site of ultrafiltration (oe) **B1**

(c) medulla identified correctly (middle region, containing pyramids) **B1**

(c) medulla function - contains the loops of Henle and collecting ducts, where water is reabsorbed and urine is concentrated (oe) **B1**

(c) (renal) pelvis identified correctly (innermost, funnel-shaped region) **B1**

(c) pelvis function - collects/funnels urine from the collecting ducts before it passes into the ureter (oe) **B1**

(c) Answer: Cortex (contains glomeruli/Bowman's capsules, site of ultrafiltration); medulla (contains loops of Henle/collecting ducts, concentrates urine); pelvis (collects urine before it enters the ureter).

(d) actual size = image size / magnification = 20 / 2.5 **M1**

(d) 8 mm (cao) **A1**

(d) Answer: 8 mm

(e) expected photograph length = actual length x magnification = 90 x 2.5 = 225 (mm) **M1**

(e) percentage error = |measured - expected| / expected x 100 = |220 - 225| / 225 x 100 **M1**

(e) 2.22% (awrt 2.22, ecf from a correct expected length) **A1**

(e) Answer: 2.22% (the measured photograph length was 2.22% less than expected).

(f) valid reason for the discrepancy, e.g. the kidney or camera may not have been perfectly flat/perpendicular when photographed (introducing parallax error/distortion), or the mm scale on the photograph may have been read imprecisely (oe) **M1**

(f) a valid, linked improvement, e.g. photograph the kidney directly from above, on a flat surface, with the camera perpendicular to it, or use digital image analysis software or vernier callipers to measure the photograph more precisely (oe) **A1**

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(f) further creditable evaluative point, e.g. repeating the photograph/measurement and calculating a mean would reduce the impact of random measurement error (oe) **B1**

(f) Answer: For example, the kidney may not have been perfectly perpendicular to the camera (parallax error); photographing it flat and directly from above, and using more precise measuring equipment, would reduce this error.

(g) use light microscopy of a thin, stained section of kidney tissue (or an electron micrograph, for finer detail such as podocyte foot processes/filtration slits) **M1**

(g) the glomerulus and Bowman's capsule are microscopic structures, far too small to resolve with the naked eye (or hand lens) used in gross dissection **A1**

(g) a light microscope provides sufficient magnification and resolution to see the glomerulus and Bowman's capsule, though an electron microscope would be needed to resolve podocyte foot processes/filtration slits, as these are smaller than the resolution limit of light microscopy (oe) **B1**

(g) Answer: Light microscopy (or electron microscopy for finer detail) of a thin, stained kidney section; gross dissection alone cannot resolve microscopic structures like the glomerulus, which are far too small to see with the naked eye.

(h) fresh tissue better preserves the natural size, texture and colour distinction between regions (before autolysis/decomposition alters the tissue), improving the accuracy of identification and any measurements taken **B1**

(h) if dissection cannot occur immediately, the kidney should be refrigerated (or frozen) to slow decomposition/autolysis/bacterial action **B1**

(h) preservation in a fixative (e.g. formalin) may cause the tissue to shrink or harden, which could introduce error into any linear measurements or magnification calculations taken from the tissue (oe) **B1**

(h) Answer: Fresh tissue preserves natural structure and colour, improving accuracy; if delayed, the kidney should be refrigerated or frozen, since fixatives such as formalin can shrink or harden tissue and distort measurements.

(i) using three (or more) kidneys accounts for natural biological variation between individual animals (e.g. differences in size, age or sex), rather than relying on a single, possibly atypical, kidney **M1**

(i) calculating a mean value from repeated biological replicates gives a more representative and reliable estimate of the typical dimension, and allows any anomalous results to be identified (oe) **A1**

(i) Answer: Using several kidneys accounts for natural variation between individual animals; taking a mean of repeated biological replicates gives a more reliable, representative estimate and helps identify anomalies.

Question 3

(a) surface area = 4 x π x 1^2 = 12.57 (cm^2); volume = 4/3 x π x 1^3 = 4.19 (cm^3) **M1**

(a) SA:V ratio = 12.57 / 4.19 = 3.00 cm^{-1} (cao, awrt 3.00; allow the shortcut SA:V = 3/r for full credit) **A1**

(a) Answer: 3.00 cm^{-1} (a ratio of 3:1).

(b) surface area = 4 x π x 5^2 = 314 (cm^2); volume = 4/3 x π x 5^3 = 524 (cm^3); ratio = 314 / 524 = 0.600 cm^{-1} (cao, awrt 0.600; allow the shortcut SA:V = 3/r) **M1**

(b) as the radius (size) of a sphere increases, the SA:V ratio decreases (oe) **A1**

(b) Answer: 0.600 cm^{-1}; the SA:V ratio decreases as the radius (size) of the sphere increases.

(c) the smaller sphere (small mammal) has a much higher SA:V ratio (3.00 cm^{-1}) than the larger sphere (0.600 cm^{-1}), meaning it has a proportionally larger surface area, relative to its volume (mass) of heat-generating tissue **M1**

(c) so small mammals lose heat to the environment faster, relative to their body mass, than large mammals, and must generate/replace heat at a proportionally higher rate to maintain a constant core temperature **A1**

(c) valid suggested adaptation, e.g. a thick fur coat or layer of insulating fat relative to body size, a more compact body shape with a lower SA:V ratio (e.g. shorter limbs/ears), huddling in groups to reduce effective surface area, or behavioural thermoregulation such as nesting/burrowing (any one, well explained) Do not credit a higher metabolic rate alone: it increases heat production rather than reducing heat loss. **B1**

(c) Answer: The high SA:V ratio of small mammals means proportionally more heat is lost through the surface than is generated in the volume, so they lose heat faster relative to body mass; adaptations such as thick fur, a compact body shape, or huddling reduce this heat loss.

(d) small mammal: 25 x 12 = 300 J per hour **M1**

(d) large mammal: 4000 x 12 = 48 000 J per hour **M1**

(d) at thermal equilibrium, each mammal must lose 12 J per gram per hour, equal to its heat generation per gram; neither requires greater heat loss per gram (oe) **A1**

(d) Answer: Small mammal = 300 J per hour; large mammal = 48 000 J per hour. At thermal equilibrium both must lose 12 J per gram per hour. Their different SA:V ratios affect heat-transfer capacity, but do not imply a different required heat loss per gram.

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