

Worked solutions

Pages 1–4 Carbohydrates and lipids

Grade booster

(a) Polysaccharide (1)

(b) Mark = 0 out of 1

Examiner comment: The reaction is a condensation reaction but the **bond** formed is a glycosidic bond, so the answer is wrong.

Full answer:

Glycosidic (1)

(c) Starch is a polymer of glucose but inulin is a polymer of fructose. (1) Some starch molecules are branched/coiled/much larger but inulin molecules are unbranched/straight/smaller. (1)

(d) Because starch molecules are either coiled or branched, (1) they pack glucose molecules more densely (1) than the fructose molecules in inulin, so the storage is more efficient.

	Inulin solution	Starch solution
Colour	Yellow	Blue/black
Result	Negative	Positive
	(1)	(1)

(f) Testing with Benedict's solution would give an orange precipitate (1) because fructose is a reducing sugar (1) and acid hydrolysis of inulin would produce fructose (1)

Exam-style questions

1 a A is glycogen; B is cellulose. (1)

b Glycogen is formed from α -glucose but cellulose is formed from β -glucose, (1) glycogen is branched but cellulose is unbranched, (1) alternate glucose units are upside down in the cellulose molecule, they are all the same way up in the glycogen molecule. (1)

c Branching gives a compact molecule with a high density of glucose units, which is good for efficient storage of respiratory substrate (1); or there are many chain 'ends' which allows the rapid removal of glucose units for respiration. (1)

d Long, straight chains allow them to line up alongside one another; (1) many molecules combine in fibrils to give strength; (1) many hydrogen bonds link molecules in fibril, preventing stretching. (1)

2 a Y is maltose; Z is sucrose. (1)

b Sucrose is made up of two different monosaccharides, glucose and fructose, so there are two spots on the chromatogram (Z). (1) Maltose is only made up of glucose, so there is one spot on the chromatogram (Y); (1) but it is darker because heating it with acid produces twice the concentration of glucose (1).

c W is fructose; X is glucose. (1)

d X is glucose because it is at the same position as maltose solution after heating with acid. (1)

Solution	Result
Maltose	+
Sucrose	– (1)
W	+
X	+ (1)
Y	++
Z	++ (1)

Pages 5–8 Proteins

Grade booster

(a) As more product is formed, increasing colour causes an increase in the absorbance of the solution. (1)

(b) Change in absorbance = $0.52 - 0.31 = 0.21$ (1)

$$\text{Rate of change} = \frac{0.21}{60} = 0.0035 \text{ s}^{-1} \text{ (1)}$$

(c) The curve is steep at low substrate concentrations because there are more enzyme molecules than substrate molecules, (1) so increasing substrate concentration causes a sharp increase in rate. At high substrate concentrations, the enzyme molecules become saturated (1) with substrate molecules and the rate cannot be increased further, so the curve flattens.

(d) A non-competitive (1) inhibitor because curve B shows that increasing the substrate concentration does not change the inhibition. The effect of a competitive inhibitor would be reduced by adding more substrate whereas here, the inhibition remains fairly constant. (1)

(e) Mark = 1 out of 3

Examiner comment: The answer correctly states that a non-competitive inhibitor binds to a part of the enzyme other than the active site, but then says 'it' is no longer complementary to the substrate. Instead it should have said the shape of the molecules is changed so the **active site** is no longer complementary to the substrate.

Full answer:

A non-competitive inhibitor binds to the enzyme somewhere other than the active site. (1) This changes the three-dimensional shape of the molecule (1) so the active site is no longer complementary to the substrate. (1)

Exam-style questions

1 Proteins are polymers of amino acids (1), joined by peptide bonds/linked by condensation reactions. (1) The sequence of amino acids forms the primary structure.

(1) The secondary structure is the way that different parts of the polypeptide coil or fold. (1) The overall three-dimensional shape of the molecule is the tertiary structure. (1) The secondary structure is stabilised by hydrogen bonds, (1) while the tertiary structure is stabilised by hydrogen, ionic and covalent bonds (such as disulfide bridges) (1). Some proteins contain more than one polypeptide, in which case they have quaternary structure. (1) (5 max)

2 a enzyme concentration (1), substrate concentration (1), pH (1) (2 max)

$$\text{b } 30^\circ\text{C} = \frac{10}{60} \times 60 = 51 \text{ g dm}^{-3} \text{ s}^{-1} \text{ (1)}$$

$$50 \frac{10}{2} \times 60 = 270 \text{ g dm}^{-3} \text{ s}^{-1} \text{ (1) 50}$$

- c The enzyme and substrate molecules have less kinetic energy (1) at 30°C, so there are fewer collisions and fewer enzyme-substrate complexes formed (1) in the same period of time, so the rate is slower.
- d After 5 minutes, the enzyme molecules are denatured (1) by the high temperature. The tertiary structure of the active sites is altered (1) and is no longer complementary to the substrate (1).
- e Measure the rate of substrate disappearance. (1)

Pages 9–12 Nucleic acids

Grade booster

- (a) DNA helicase (1)
- (b) Arrow pointing right. (1) The enzyme is moving to the right because there are single strands of DNA already separated on the left. (1)
- (c) Mark = 0 out of 2

Examiner comment: The role of DNA polymerase is to catalyse condensation reactions between new nucleotides once they are in place, not to add new nucleotides. New nucleotides are free in solution and collide randomly, forming hydrogen bonds with exposed complementary bases. Neither mark is gained.

Full answer:

DNA polymerase forms phosphodiester bonds in condensation reactions (1) between adjacent nucleotides. (1)

- (d) The active sites of the enzymes have very specific shapes so they can only bind with the new nucleotides one way round. (1)
- (e) The DNA molecules in prokaryotes are short, circular molecules, whereas those in eukaryotes are much longer so would take much more time (1) to copy. Having multiple points of replication means that sections are copied at the same time, (1) shortening the time taken to copy the whole molecule.
- (f) $\frac{80\,600}{4} = 20\,150$ base pairs per section (1)
 $\frac{20\,150}{50} = 403$ seconds (1)

Exam-style questions

- 1
 - a Transferring genetic information from the DNA to ribosomes. (1)
 - b The pentose in RNA nucleotides is ribose and in DNA nucleotides, it is deoxyribose. (1) RNA has the base uracil instead of thymine. (1) RNA molecules are single stranded, DNA molecules are double stranded. (1)
 - c There are hydrogen bonds between complementary bases (1) in parts of the molecules where the single strand folds back on itself. (1)
 - d Proteins have a specific three-dimensional shape (1) so if the RNA is to fit together (1) with the proteins, it must also have a specific three-dimensional shape.
- 2 Each time a DNA molecule is replicated, the two new DNA molecules each contain one original strand (1) and one replicated strand (1). Half of each new molecule is conserved (1) from the previous molecule so it is semi-conserved.

Pages 13–16 Water, inorganic ions and ATP

Grade booster

- (a) Chloride ion / Cl^- (1)
- (b) The membranes of the cells lining the ileum contain amino acid carrier proteins (1). Amino acids and sodium ions bind (1) to the carrier protein. This causes the carrier protein to change shape and move both the amino acids and the sodium ions across the membrane. The amino acid is effectively ‘pulled’ across (1) by the steep sodium ion concentration gradient. This is called co-transport. (1)
- (c) The more hydrogen ions in a solution, the lower the pH. (1) The relationship is logarithmic so there has to be an increasingly large increase in the hydrogen ion concentration to lower the pH by the same amount. (1)
- (d) $-7.4 = \log_{10} [\text{H}^+]$
 $[\text{H}^+] = 10^{-7.4} = 3.98 \times 10^{-8} \text{ mol dm}^{-3}$ (1)
- (e) Mark = 2 out of 3

Examiner comment: The first two points are covered well. But the question says ‘even a small change in the pH’ so it does not suggest enough to cause denaturation. The answer says ‘no longer complementary...’, which implies denaturation so the last mark is not awarded.

Full answer:

The change in the number of hydrogen ions around the molecule affects hydrogen bonds that maintain the secondary and tertiary structure (1). This can change the tertiary structure of the active site (1) so that it no longer has the optimum affinity for its substrate and its activity is reduced. (1)

Exam-style questions

- 1 6 of the following points, properties must be explained or no marks: Water is a solvent (1) so many metabolic reactions take place in water. (1) Water molecules show cohesion (1) which helps to maintain water columns in the xylem of plants. (1) Water has a high heat capacity, (1) protecting aquatic animals from sudden changes in temperature in ponds and lakes. (1) Water is a metabolite, (1) taking part in important reactions such as hydrolysis and condensation. (1) Water has a high latent heat of vaporisation (1) so it provides effective cooling for little loss of water. (1)
- 2
 - a Iron ions are a component of haemoglobin (1), important for the transport of oxygen. (1)
 - b Removal of blood removes red blood cells containing haemoglobin. (1) Stored iron ions are then used to make more haemoglobin (1) to replace the lost red blood cells.
 - c Lipoprotein is used to transport lipid because it is insoluble in water (1). This suggests iron ions are also relatively insoluble in water. (1)

Pages 17–20 Cell structure 1

Grade booster

- (a) Large circular space on diagram labelled nucleus (1)
- (b) Mark = 0 out of 2

Examiner comment: Insufficient detail for either mark. This answer requires the mention of DNA **and** proteins in the form of **chromosomes**.

Full answer:

DNA and proteins (1) in the form of chromosomes. (1)

- (c) X is the nucleolus, (1) W is a nuclear pore (1) and Y is a ribosome. (1)
- (d) Rough endoplasmic reticulum, which synthesises proteins (1) for export from the cell. (1)
- (e) Diameter of nucleus = $8.25 \mu\text{m}$ (1)
 Area of a circle = πr^2
 Cross section of nucleus = $3.142 \times 4^2 = 50.3 \mu\text{m}^2$ (1)
- (f) Magnification = $\frac{\text{Size of image}}{\text{Size of real object}} = \frac{2.5 \text{ cm}}{4 \mu\text{m}} = 2.5 \times \frac{10^{-4}}{4} = \times 6250$ (2)

Exam-style questions

- 1 a Iodine in potassium iodide solution. (1) A cell wall (1) and part of a chloroplast are present. (1)
- b There is part of a large vacuole present and algal cells do not have a single central cell vacuole. (1)
- c It is a chloroplast. (1) Chloroplasts are surrounded by a double membrane. (1) Inside are groups of disc-shaped membrane-bound structures (1) surrounded by a water-based solution. (1)
- d Cellulose molecules are organised into fibres. (1) Many molecules are lined up parallel with each other (1) and are linked together by hydrogen bonds. (1) Many fibres are criss-crossed in all directions to form a thick layer.
- 2 a A tissue is a group of similar cells (1) specialised for the same function. (1)
- b Because there are many cells (1) in a multicellular organism, individual cells do not have to carry out all of the functions (1) necessary for the organisms to survive, so they can be specialised for one particular function.
- c One end of the cell is elongated (1) to accommodate a stack of many (1) disc-shaped membrane-bound structures in the path of light entering the transparent (1) end of the cell.
- d The circular end of each cell has a very small area (1) so two cells beside one another are able to distinguish between two points of light very close to one another. (1)

Pages 21–24 Cell structure 2

Grade booster

- (a) The cell has a capsule outside the cell wall. (1) There is no visible nucleus (1) but there is a loose circular DNA molecule. (1)
- (b) Mark = 1 out of 2
 Examiner comment: 'Small ribosomes' might not be awarded the mark; better to write 'ribosomes smaller than those in eukaryotic cells'. Cell wall **containing** murein is better than **made of** murein.
 Full answer:
 Ribosomes that are smaller than those in eukaryotic cells (1) and a cell wall containing murein (1).
- (c) Several layers (1) of disc-shaped membrane-bound structures. (1)
- (d) To allow the maximum possible amount of light to reach it for photosynthesis. (1)

- (e) Length of the cell is three times that of the scale bar so 1500 nm . (1)
 $\frac{1500}{1000} = 1.5 \mu\text{m}$ (1)

Exam-style questions

- 1 Calibrate the graticule (1) to find what each graticule unit represents (1) in terms of length. This involves looking at the graticule superimposed (1) on a scale on a special microscope slide. This has to be done for the particular objective lens (1) that will be used for observing the guard cell. Look at the eyepiece graticule superimposed on the prepared slide and measure the guard cell. (1)
- 2 a Mitochondrion (1)
- b Aerobic respiration (1)
- c Magnification = size of image in mm $\times \frac{1000}{\text{size of real object}} = \frac{68000}{5} = \times 13600$ (2)
- d Transmission electron microscope (1), because the internal structure of the mitochondrion is visible. (1)
- e A number of folds of the inner membrane called cristae (1) project into the internal space (1) of the mitochondrion.
- f Homogenise the tissue (1), centrifuge (1) the homogenate at a suitable speed to cause the larger nuclei to form a pellet (1). Centrifuge the supernatant at a higher speed to cause the smaller mitochondria to form a pellet. (1)

Pages 25–28 Mitosis and binary fission

Grade booster

- (a) The cytoplasm must be large enough for each daughter cell to receive a share containing sufficient enzyme molecules and organelles. (1)
- (b) Mark = 1 out of 2
 Examiner comment: the idea of the nucleus controlling the cell is correct, but the student should add limitations of diffusion over long distances (in terms of chemical communication).
 Full answer:
 The distance across the cell would be too far for diffusion to work fast enough (1) for the nucleus to control the cell. (1)
- (c) 2:1 (1)
- (d) (i) DNA replication (1) and cell growth (1)
 (ii) Mitosis (1)
 (iii) Cytokinesis (1)
- (e) Between B and C (1) because chromosomes shorten and thicken before mitosis begins. (1)

Exam-style questions

- 1 a 10 minutes (1) because the mean distance has stopped changing as all the centromeres have arrived at the equator. (1)
- b From the tangent, extended to the x-axis, distance moved (AB) of $25 \mu\text{m}$ in 50 minutes (BC)
 Initial rate of movement is $\frac{AB}{BC} = \frac{25}{50} = 0.5 \mu\text{m min}^{-1}$. (1)
- c For the first 50 minutes, the rate of movement falls steadily (1), after which it falls increasingly slowly. (1)
- d If the poles are moving apart at the same time as the centromeres are moving towards them (1) at a fixed rate, they will appear to be moving more slowly. (1)

Pages 29–32 Transport across cell membranes 1**Grade booster**

- (a) P is polar so is hydrophilic (1) and S is non-polar so is hydrophobic. (1)
- (b) Part Q is in the same layer as the hydrophilic heads of the phospholipid molecules, (1) which suggests that it must also be hydrophilic. (1)
- (c) Unsaturated fatty acids (1)
- (d) Mark = 2 out of 2

Examiner comment: A good answer that uses the information in the question and correctly predicts the effect of the bent tail as the opposite of cholesterol.

Full answer:

The bent fatty acids hold phospholipids further apart (1) so they are able to move around more easily. (1)

- (e) Protein molecules can move around among mobile phospholipid molecules. (1) If the phospholipid molecules are less mobile because of cholesterol molecules, protein movement will also be restricted. (1) If the phospholipid molecules are more mobile because of unsaturated fatty acids, protein movement through them will be easier. (1)

Exam-style questions

- 1 Oxygen and carbon dioxide are small (1) non-polar molecules (1) that can diffuse between the phospholipid molecules. Water is a polar molecule but is still small enough (1) to diffuse between the phospholipid molecules but less easily than gas molecules because its polarity makes it much less soluble in lipid. (1) Monosaccharides are also polar but they are too large (1) to diffuse between phospholipid molecules. Ions are small but are charged (1) so are repelled (1) by the layer of non-polar phospholipid tails. (6 max)
- 2 a The prokaryotic bacterial cell has a high ratio of phospholipid to other lipid (1) whereas the eukaryotic cell membranes have a high ratio of other lipid to phospholipid / the ratio is reversed. (1)
- b If different quantities of the different membranes were used for the analysis, percentages make the lipid compositions comparable. (1)
- c Glycolipids are found on the surface of eukaryotic cells such as liver cells but not on their organelles (1) because they are involved in cell recognition (1). The bacterial cell has a cell wall (1) immediately outside its cell-surface membrane instead of glycolipids.
- d Cholesterol restricts the movement of other biological molecules in the cell membrane that makes the membrane more stable. (1)
- e Lysosomes are a type of vesicle formed from the Golgi apparatus membrane. (1)

Pages 33–36 Transport across cell membranes 2**Grade booster**

- (a) The mass of chloride ions would be divided by the time the slices were in the solution. (1) Suitable units are $\mu\text{g min}^{-1}$. (1)
- (b) Mark = 0 out of 1

Examiner comment: Faster uptake at a higher temperature could also occur with simple or facilitated diffusion due to higher kinetic energy. The arrow indicating the concentration of chloride ions in the slices at the start of the two hours shows that rate of uptake continues to increase even when the external concentration was higher than that in the cells.

Full answer:

Uptake occurs against the concentration gradient. (1)

- (c) The carrier protein is also able to act as an ATP hydrolase. (1)
- (d) The rate of uptake increases, then reaches a plateau (1) at higher chloride ion concentrations because the carrier proteins are saturated. (1)
- (e) Respiration in the carrot cells is faster at 18°C so more ATP is available to carrier proteins. (1) Molecules and ions have greater kinetic energy (1) so more chance of collisions between chloride ions and carrier and ATP molecules and carrier. (1)

Exam-style questions

- 1 a Cell fractionation (1) and centrifugation (1)
- b $\frac{(10 - 2.8)}{40} = \frac{7.2}{40} = 0.18 \text{ arbitrary units min}^{-1}$ (1)
- c Tube A (1) because without ATP hydrolase activity, the carrier proteins cannot transport calcium ions into the endoplasmic reticulum fragments so they remain in the solution. (1)
- d Uptake in tube B is greater than in tube A, (1) showing that ATP hydrolysis is involved (1) in the uptake. The concentration in the solution in tube B fell to zero (1) indicating that uptake occurred against a concentration gradient. (1)

2

Transport	Concentration gradient required	ATP required	Channel proteins involved	Carrier proteins involved
Simple diffusion	Y	N	N	N
Facilitated diffusion	N	N	N	N
Active transport	N	N	N	N

(1)

(1)

(1)

(1)

Pages 37–40 Cell recognition and the immune system 1**Grade booster**

- (a) Passive immunity (1) because antibodies were given directly (1) to the non-human primates rather than stimulating an immune response by injecting an antigen.
- (b) So the antibodies can bind to the viral glycoproteins before phagocytosis occurs. (1)
- (c) Mark = 2 out of 3

Examiner comment: Quite a good answer, but it does not explain that without the antibody bound to their glycoproteins, the virus could avoid phagocytosis and replicate inside the cell.

Full answer:

The antibodies block the NPC1 binding site (1) so viruses are destroyed by phagocytosis (1) and cannot replicate inside the cell (1) as they normally do.

- (d) Antibody molecules do not remain very long in the blood circulation. Memory cells remain for far longer (1) and retain the ability to produce the antibodies. (1)
- (e) Because it would not be ethical to deliberately infect humans with the Ebola virus without knowing if it could be cured. (1)

Exam-style questions

- 1 Monoclonal antibodies are immobilised (1) on an inert base. A sample to be tested containing antigen is added and antigens bind to immobile antibodies (1). More antibody molecules attached to enzyme molecules are added (1) and bind to antigens bound to immobile antibodies. (1) Any unbound antibody-enzyme complexes are washed away. (1) A substrate that changes from colourless to coloured (1) in the presence of the enzyme is added and left for a fixed time. (1) The intensity of the colour indicates the amount of antigen present. (1) (max 6)
- 2 a Monoclonal antibodies are antibodies from one clone of plasma cells. (1)
- b When Rituximab binds to B cells (1), helper T cells stimulate (1) cytotoxic T cells which kill (1) the B cells.
- c The patient will not be able to respond to any new infection (1) because there will be no B lymphocytes available for clonal selection. (1)
- d Existing plasma cells will be unaffected and will continue producing antibodies to antigens already encountered. (1) After treatment finishes, stem cells will be unaffected and will be able to produce more B lymphocytes. (1)

Pages 41–44 Cell recognition and the immune system 2

Grade booster

- (a) Rabbits are not affected by the neurotoxin. (1)
- (b) The second dose will stimulate a larger immune response because of the memory cells formed (1) after the first dose, so more antibodies will be produced. (1)

- (c) Mark = 1 out of 3

Examiner comment: Similar shape would be better than same shape, although idea allowed for 1 mark. Saying 'them' twice makes it unclear which molecule is being referred to. Location of receptors not stated.

Full answer:

Antibodies have binding sites that have a similar shape to a part of the toxin molecules. (1) The antibodies bind to the toxin molecules changing their shape (1) and preventing the toxin molecules from binding to the nerve cell receptors. (1)

- (d) The rabbit antibody acts as an antigen (1) and causes a large immune response on the second exposure. (1)

Exam-style questions

- 1 a It means that the person has produced antibodies to the legionella bacteria. (1)
- b The test well has a layer of legionella antigens (1) attached (1) to it.
- c The first reagent contains legionella antibodies (1) attached to enzyme molecules. (1)

- d The second test reagent is a substrate for the enzyme (1) contained in the first reagent. The enzyme catalyses a reaction that produces a coloured product. (1) The intensity of the colour measures the antibodies (1) in the urine sample.

Pages 45–48 Gas exchange

Grade booster

- (a) Correct the label: they are gill filaments, not lamellae. (1) 'Connect' gill rakers to the gill bar; there are gaps in the drawing. (1)

- (b) Blood arrow (labelled) from right to left; (1) water arrow (labelled) from left to right (1)

- (c) Mark = 1 out of 3

Examiner comment: The answer refers only to oxygen rather than to gas exchange or to oxygen and carbon dioxide. Neither does it fully explain that the concentration gradients for **both** are maintained as blood flows from one side of the lamella to the other.

Full answer:

More diffusion of oxygen and carbon dioxide occurs (1) because concentration gradients for both are maintained (1) as blood flows from one side of the lamella to the other. (1)

- (d) Gill lamellae (1)

Exam-style questions

- 1 For the organism with radius $6\mu\text{m}$:

$$\text{Volume} = \frac{4}{3}\pi r^3 = \frac{4}{3} \times 3.142 \times 216 = 904.9\mu\text{m}^3$$

$$\text{Surface area} = 4\pi r^2 = 4 \times 3.142 \times 36 = 452.5\mu\text{m}^2 \text{ (1)}$$

For the organism with radius $8\mu\text{m}$:

$$\text{Volume} = \frac{4}{3}\pi r^3 = \frac{4}{3} \times 3.142 \times 512 = 2144.9\mu\text{m}^3$$

$$\text{Surface area} = 4\pi r^2 = 4 \times 3.142 \times 64 = 804.4\mu\text{m}^2 \text{ (1)}$$

So the volume increases by 2.4 times while the surface area only increases by 1.7 times, (1) so surface area does not keep pace (1) with the increase in volume.

- 2 a Calibrate the graticule. (1) Use the graticule to measure the diameter of a field of view for the objective lens being used. (1) Calculate the area of the field of view. (1) Count the stomata in the field of view (1) and calculate the number of stomata per unit area.
- b High marsh species that grow in drier conditions have a lower stomatal density and stomata in deeper furrows. (1) Both of these features will reduce the rate of water loss by transpiration. There will be less **diffusion** of water vapour from fewer stomata (1) and the furrows will trap humid air above the stomata, reducing the **water potential gradient** (1) and slowing the rate of diffusion.

Pages 49–52 Digestion and absorption

Grade booster

- (a) Mixing emulsifies the lipid (1) and mixes it with bile salts. Bile salts mixed into the smaller droplets prevent them from merging back into large droplets. (1)
- (b) Smaller droplets have a higher surface area to volume ratio (1) than large droplets, so access to substrate by lipase and lipid hydrolysis is faster. (1)
- (c) Micelles (1)
- (d) Mark = 1 out of 3

Examiner comment: Lipid is hydrolysed to fatty acids, glycerol and monoglyceride but glycerol is not found in micelles. Micelles are about 200 times smaller than the lipid droplets in an emulsion.

Full answer:

Micelles are very tiny droplets (1) consisting of monoglyceride and fatty acids (1) together with bile salts. (1)

- (e) Micelles transport the monoglycerides and fatty acids to the cell-surface membrane (1) of the epithelial cell, where they can be absorbed. (1)
- (f) Simple diffusion (1)

Exam-style questions

- 1 a A is without bile salts; B is with bile salts. (1)
- b rate without bile salts = $\frac{(100 - 85)}{(10 \times 60)} = \frac{15}{600}$
 $= 2.5 \times 10^{-2} \text{ mg s}^{-1}$ (1)
- rate with bile salts = $\frac{(100 - 65)}{(10 \times 60)} = \frac{35}{600}$
 $= 5.8 \times 10^{-2} \text{ mg s}^{-1}$ (1)
- c To emulsify the lipid in each mixture. (1)
- d With bile salts in the mixture, the emulsion remained during the incubation (1) so lipase was able to act on a larger surface area of substrate (1) and hydrolyse the lipid more quickly. (1) Without bile salts, the lipid droplets merged back into large droplets in an aqueous solution, so there was relatively less surface area for lipase to act on so hydrolysis was slower. (1)
- 2 Endopeptidases in the stomach and from the pancreas hydrolyse peptide bonds (1) within polypeptides (1) to give shortened peptide chains. Exopeptidases from the pancreas and in the duodenum remove terminal amino acids (1) from both ends of the shorter peptide chains. Membrane bound dipeptidases (1) in the ileum hydrolyse dipeptides to amino acids. (1)

Pages 53–56 Mass transport in animals – haemoglobin

Grade booster

- (a) An increased carbon dioxide concentration reduces the pH and a decreased carbon dioxide concentration raises the pH. (1)
- (b) Mark = 1 out of 2

Examiner comment: The answer does not say that the carbon dioxide comes from increased **respiration** of active muscle.

Full answer:

Curve at pH 7.2, (1) because active muscle produces more carbon dioxide from respiration, (1) which lowers the pH.

- (c) Bohr effect (1)
- (d) At the partial pressure of oxygen in active muscle, at pH 7.2, the percentage saturation of haemoglobin is reduced by 15% (1) compared to pH 7.6, (1) leading to greater unloading of oxygen for respiration. (1)
- (e) Saturation at pH 7.6 for 15 kPa = 95%, saturation at pH 7.2 for 5 kPa is 50% (1)
- It decreases by $(95 - 50) = 45\%$. (1)

Exam-style questions

- 1 a Their haemoglobin has a lower affinity for oxygen (1) so more oxygen is unloaded at their respiring tissues. (1)
- b There is a lower partial pressure of oxygen in the atmosphere. With a lower affinity for oxygen, the loading of their haemoglobin with oxygen is less effective so a faster breathing rate helps to compensate for this. (1)
- c Red blood cells contain haemoglobin (1) so more red blood cells increase the amount of oxygen that can be transported. (1)
- 2 a When the first haem group forms a bond with the first oxygen, the four globins have to move a little relative (1) to each other. Once they have moved, the next oxygen can bind more easily (1), moving globins a little more, allowing the third and fourth oxygens to bind very easily. (1)
- b It makes the dissociation curve s-shaped (1) so more oxygen is unloaded at the partial pressure of respiring tissues. (1)

Pages 57–60 Mass transport in animals – blood circulation

Grade booster

Full answer:

Blood enters a capillary at relatively high hydrostatic pressure. (1) Water is forced out of the capillary into the tissue fluid through narrow gaps between cells. (1) Some small solute molecules and inorganic ions move with the water. Larger plasma proteins are unable to fit through the gaps. (1) As blood moves along the capillary, the hydrostatic pressure and the water potential fall. (1) At the venule end, water moves back into the capillary across capillary cell membranes by osmosis. (1) Excess tissue fluid enters lymph vessels and returns to veins in the circulatory system as lymph. (1)

Exam-style questions

- 1 a People of the same sex, age and health (1) as the experimental groups who have heart failure (1) but are either (i) within the normal range for percentage of body fat or (ii) within the normal range for BMI. (1)
- b Both methods are effective indicators. (1) People with a high BMI or a high percentage of body fat experienced a similar percentage survival (1) after 28 months.
- In both cases there was a significant difference (1) between the control group and the experimental group, with probability values of less than 0.05.
- 2 Blood enters a capillary at relatively high hydrostatic pressure. (1) Water is forced out of the capillary into the tissue fluid through narrow gaps between cells. (1) Some small solute molecules and inorganic ions move with the water. Larger plasma proteins are unable to fit through the gaps. (1) As blood moves along the capillary, the hydrostatic pressure and the water potential fall. (1) At the venule end, water moves back into the capillary across capillary cell membranes by osmosis. (1) Excess tissue fluid enters lymph vessels and returns to veins in the circulatory system as lymph. (1)

Pages 61–64 Mass transport in plants**Grade booster**

- (a) Phloem (1)
- (b) The most important sinks are the flowers and the seed pods. (1) Translocation is supplying organic substances from the older leaves to support seed development. (1) A much smaller amount of translocation to the roots is occurring. (1)
- (c) No. (1) Even though the value for young leaves is slightly higher than the stem, the SD bars overlap. The radioactivity in the young leaves is probably not significantly different from that in the stem. (1)
- (d) Mark = 2 out of 3

Examiner comment: The answer outlines chromatography correctly but the TLC plate has to be placed on photographic film, which is then developed because the radioactivity in the spots cannot be made visible on the plate itself. There is a clue in the stem of the question.

Full answer:

The plant extracts are placed as concentrated spots on the origin of the TLC plate. (1) The bottom of the plate is placed in a solvent (1) and allowed to run. The plate is then left on photographic film (1), which is then developed.

- (e) A lot of the tracer is still in the donor leaf and the stem (1). There has not been enough time for tracer to be translocated to other parts of the plant. (1)

Exam-style questions

- 1 In the mesophyll of the leaf, sugars are actively transported into phloem sieve cells (1) by companion cells. (1) This lowers the water potential of the sieve cells so water moves into them by osmosis. (1) The increased hydrostatic pressure forces the sieve tube contents to move by mass flow (1) towards whichever sink (1) is the priority, depending on where the plant is in its life cycle.
- 2 a distance moved by dye is $13 - 5 = 8$ sections; distance = 8 sections $\times$ 5 mm per section = 40 mm; time taken is 600 seconds
 $\text{Rate} = \frac{40}{600}$ (1) = $0.066666 = 6.7 \times 10^{-2} \text{ mm s}^{-1}$ (to 2 s.f.) (1)
- b The 5 minute interval results are not very precise (1) to begin with. The rate of transport is speeding up as tension builds up (1) in the xylem again following de-rooting.
- c The rate of transport in de-rooted plants may not be the same as in intact plants. (1) Time was only measured to the nearest minute and distance to the nearest 0.5 cm (1) so the calculated rate may not be very accurate. (1)

Pages 65–68 DNA, genes and chromosomes**Grade booster**

- (a) 1 Chloroplast DNA has no histones associated with it but nuclear DNA does. (1)
 2 Chloroplast DNA is a short molecule rather than the very long DNA molecules in the nucleus. (1)
- (b) (i) tRNA gene (1) (ii) RNA polymerase gene (1)
- (c) It is a quaternary protein (1) because it consists of more than one polypeptide. (1)
- (d) $\frac{12\,1024}{2} = 60\,512$ nucleotides per half circle (1)

$$\text{Time taken} = \frac{60512}{220} = 275 \text{ s} = 4.6 \text{ minutes (1)}$$

- (e) Mark = 1 out of 2

Examiner comment: The answer does suggest mosses, liverworts and club-mosses are closely related to each other, but does not mention other plants.

Full answer:

It suggests mosses, liverworts and club-mosses are more closely related to each other (1) than they are to other plants. (1)

Exam-style questions

- 1 a X is a DNA molecule; (1) Y is a protein/histone molecule. (1)
- b Very long DNA molecules are made much more compact. (1)
- c A gene (1)
- d Non-coding sequences contain base sequences of variable length repeated (1) multiple times.
- e The amino acid sequence of a polypeptide (1) or the nucleotide sequence of a functional RNA/tRNA/rRNA. (1)
- f $292 + 50 = 342$ nucleotides, but DNA is double-stranded so that is $\frac{342}{2} = 171$ base pairs long per repeat. (1)
 There are 8 histone molecules per repeat, so total number of histone molecules
 $= \frac{3420}{171} \times 8 = 160$. (1)
- 2 Some proteins have a quaternary structure (1) so they are made of more than one polypeptide (1), which requires more than one gene. (1) Some genes code for functional RNA rather than protein. (1) Parts of some genes are introns (1) that do not code for amino acid sequences. (1)

Pages 69–72 DNA and protein synthesis**Grade booster**

- (a) Q is water (1) and the enzyme is ATP hydrolase. (1)
- (b) R is an adenine molecule (1) and P is an inorganic phosphate group. (1)
- (c) Mark = 0 out of 2
 Examiner comment: The answer is too vague. It does not directly imply that the reaction is energy-requiring and does not use the idea of being 'coupled'.
 Full answer:
 The attachment of the amino acid requires energy (1) so is coupled to (1) the hydrolysis of ATP.
- (d) The products of the reaction are two **inorganic** phosphate groups instead of one (1) in the equation, and a molecule of adenosine with one phosphate group attached/adenosine monophosphate, instead of a molecule of adenosine diphosphate in the equation. (1)
- (e) ATP hydrolase removes one phosphate group but the enzyme in the diagram removes two. (1) The active sites of the enzymes like the one in the diagram will each have a specific shape complementary to the shape of each amino acid. (1)

Exam-style questions

- 1 Hydrogen bonds are broken (1) and DNA strands separated by helicase. (1) Only one of the DNA strands/ the 'sense' strand acts as the template. (1) Complementary (1) RNA **nucleotides** form hydrogen bonds (1) with the exposed bases along the entire length of the gene including introns as well as exons. RNA polymerase then forms phosphodiester bonds between/joins the nucleotides (1) to form a pre-mRNA molecule. This is then spliced (1) to remove the intron-equivalent/non-coding sections and join the exon-equivalent/coding sections together to form the mRNA molecule. (6 max)
- 2 a The genome of a cell is the full set of genes (1) contained in the DNA of that cell, including the genes on plasmids (1) in prokaryotic cells and the genes on mitochondrial and chloroplast DNA (1) in eukaryotic cells. However, not all the genes in a cell are expressed and genes that are expressed do not all code for proteins. Some genes code for functional RNA. (1) The proteome of a cell is the set of protein molecules (1) expressed by a cell (1) at a particular time. (5 max)
- b Four triplets code for threonine. The third base does not matter, ACX always codes for threonine. (1) This means there are more triplets/RNA codons than there are amino acids. (1)

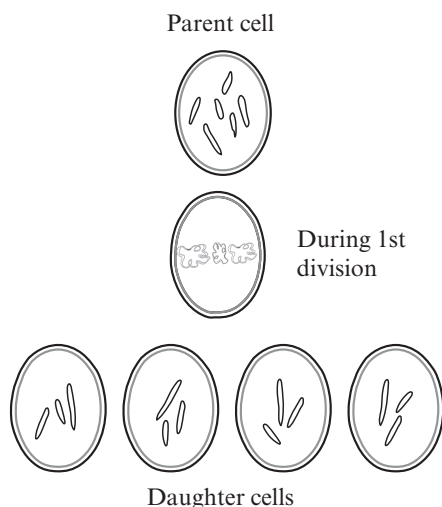
Pages 73–76 Genetic diversity arises from mutation or meiosis

Grade booster

- (a) Mark = 0 out of 2

Examiner comment: The parent cell should be shown before DNA replication occurs. The answer shows chromatids in the parent cell, so no marks. There is the right number of chromosomes in each of the daughter cells but they are drawn carelessly, all the same size, so no understanding is shown of which chromosome goes where. Small, medium and large chromosomes should be clearly visible in each cell.

Full answer:



1 mark for parent cell; 1 mark for daughter cells

- (b) Number of homologous pairs is 3 (1)
Number of combinations is $2^3 = 8$ (1)
- (c) Number of combinations of chromosomes for each gamete is 8 (1)
Number of combinations is $2^8 = 256$ (1)

- (d) Parts of homologous chromosomes that are exchanged (1) may contain different **alleles** that are recombined in different ways. (1)

Exam-style questions

- 1 a S is a spindle fibre; (1) T is a chromosome. (1)
- b The chromosome is in a V-shape because the arms of the chromosome are trailing (1) behind as the shortening spindle, S, moves it.
- c 4 (1)
- d 6 (1) because the haploid number in each of the four daughter cells will be 3 (1)
- e The daughter cells may contain different combinations of chromosomes due to the independent segregation of homologous chromosomes (1) and may contain different combinations of alleles on particular chromosome due to crossing over, or swapping of sections, (1) between homologous chromosomes.
- 2 Gene mutations to single bases (1) can occur, altering the base sequence of DNA and changing single amino acids in polypeptides. These may result in advantageous changes to the shape of proteins. (1) Independent segregation of homologous chromosomes (1) or crossing over between homologous chromosomes (1) can result in different combinations of alleles in gametes that may be advantageous. (1) Random fertilisation between genetically different gametes (1) also results in different combinations of alleles in an organism, which may be advantageous. (1) (6 max)

Pages 77–80 Genetic diversity and adaptation

Grade booster

- (a) Although the clear zone for chloramphenicol is slightly larger, the standard deviations overlap (1), which suggest that the difference is not significant. (1)
- (b) They are comparing two mean values to see if the difference between them (1) is significant.
- (c) Mark = 0 out of 2

Examiner comment: The answer confuses the *t* value and the *p* value. 'Results' cannot be significant. In this case, it is the difference between the two means that might or might not be significant.

Full answer:

The calculated *t* value (1.39) is smaller than the critical value (2.12) for a significance level of 0.05. (1) This means the difference between the mean areas is not significant. (1)

- (d) A random mutation provided a new allele giving resistance to the antibiotic. (1) Having this allele was an advantage to bacteria because they were the only ones to survive when exposed to tetracycline. (1) They passed on the allele for resistance to the next generation of bacteria (1) and over many generations, the allele for resistance increased in frequency. (1)

Exam-style questions

- 1 a Scattergram (1)
- b In deciduous woods, the snails tend to have pink shells with 1 or no bands. (1) In hedgerows and grassland, the snails tend to have yellow shells and more than 1 band. (1)

- c In woodland on bare soil and fallen leaves, pink snails with few bands are better camouflaged from thrushes (1) so more survive to pass on their alleles to the next generation. (1) This means these snails tend to be more frequent in woodland.
- Among grass stems, yellow snails with more bands (1) are better camouflaged from thrushes so more survive to pass on their alleles to the next generation. This means they tend to be more frequent in hedgerows and grasslands. (1)
- 2 Males with large horns pass on the alleles for large horns to more of the next generation (1) but although there are initially more offspring with these alleles, they die early. (1) Males with small horns pass on the alleles for small horns to fewer (1) of the next generation but these males survive longer to reproduce so overall have just as many offspring. (1) This maintains the frequency of both alleles (1) in the population.

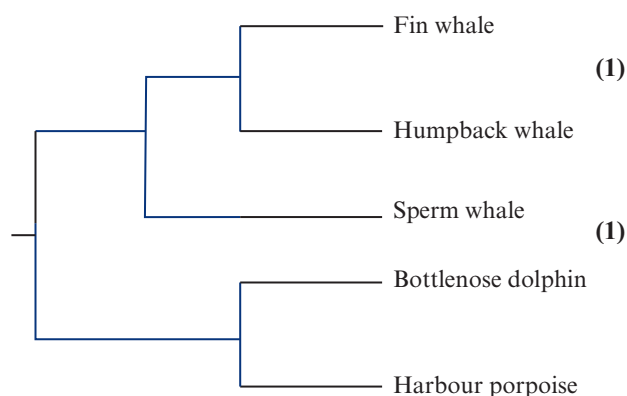
Pages 81–84 Species and taxonomy

Grade booster

- (a) Mammals are a class. (1)
- (b) Because they have teeth, sperm whales are classified as toothed whales, (1) more closely related to dolphins and porpoises than to baleen whales. (1)
- (c) This binomial name is recognisable around the world in any language. (1)
- (d) Sperm whales are more closely related to fin whales and humpback whales than they are to dolphins or porpoises. (1)
- (e) Mark = 1 out of 2

Examiner comment: Dolphin and porpoise are correctly connected to ancestor. However, results show humpback whale and fin whale to be more closely related to each other than to the sperm whale, so the sperm whale should be on its own branch.

Full answer:



Exam-style questions

- 1 a The percentage of flashes responded to increases with inter-pulse intervals between 0.8 s and 1.1 s, peaks at 65% (1) at inter-pulse intervals of 1.1 s and decreases (1) with higher inter-pulse intervals.
- b If they are not attracted by the light signal they will not approach the male and mate. (1) Females of a different species are not attracted because they respond to a different inter-pulse interval. (1)

- c They are nocturnal. (1) Behaviour dependent on seeing each other would not be effective in the dark. Light signals are visible in the dark. (1)
- 2 They can compare the base sequences of sections of DNA common to all the taxa (1) and count how many different bases (1) there are. They can compare the base sequences of mRNA (1) for proteins common to all the taxa and count how many different bases there are. They can compare the amino acid sequences (1) of proteins common to all the taxa (1) and count how many different amino acids there are. In each case, the fewer differences, the more closely related the taxa are. (1)

Pages 85–88 Investigating diversity

Grade booster

- (a) For the improved meadow:

$$N(N-1) = 32(32-1) = 992$$

$$\Sigma n(n-1) = 8(8-1) + 2(2-1) + 22(22-1) = 520 \text{ (1)}$$

$$d = \frac{992}{520} = 1.90 \text{ (1)}$$

For the unimproved meadow:

$$N(N-1) = 37(37-1) = 1332$$

$$\Sigma n(n-1) = 8(8-1) + 7(7-1) + 4(4-1) + 2(2-1)$$

$$+ 10(10-1) + 6(6-1) = 232 \text{ (1)}$$

$$d = \frac{1332}{232} = 5.74 \text{ (1)}$$

- (b) Mark = 2 out of 3

Examiner comment: The answer ignores the information in the question about fertiliser and the link between that and the information in the table about the dominance of rye grass, so loses a mark.

Full answer:

Improving the meadow has reduced the biodiversity of the plant community. (1) The addition of fertiliser promotes the growth of rye grass, which dominates the community. (1) Cutting the meadow twice a year means that flowering plants are cut before they are able to produce seed, so they cannot reproduce. (1)

- (c) Sample more 1 m² areas in each meadow and find the mean number of each species. (1) Use dice to generate random coordinates to decide on the locations of the sampling areas. (1)

Exam-style questions

- 1 a Greek wolves (1)
- b 1 allele. (1) A genetic diversity of zero means all the wolves in the population have the same allele. (1)
- c The population size was reduced so the few individuals left had only one of the alleles (1) for each gene originally present in the population and all their descendants have the same alleles. (1)
- d Slovenian wolves have a low genetic diversity but higher than Italian wolves. Separate small populations contain few alleles but different ones, (1) so when they merge again, there are more alleles (1) than for one single small population.
- 2 a Use a grid system on which to locate random coordinates produced by a random number generator. (1) Measure out a large area suitable for sampling trees at each point/use a 20 m × 20 m area positioned at each point. (1) Identify all the tree species in the area. (1)

- b The data are not suitable for calculating indices of diversity because the number of individuals of each species would be needed (1) and the data recorded only species richness and percentage tree cover. (1)

Pages 89–92 Photosynthesis 1

Grade booster

- (a) A buffer solution controls the pH while the experiment is taking place. (1) A dilute solution bursts the chloroplasts by osmosis so the electron transfer chains are in contact with DCPIP molecules. (1)
- (b) The tube containing boiled extract remained blue (1) but the tube containing unboiled extract became green. (1)
- (c) Dehydrogenase enzymes (1) in the electron transfer chains reduce DCPIP molecules (1) instead of NADP molecules (1) causing the DCPIP solution to lose its blue colour.
- (d) Mark = 2 out of 3

Examiner comment: The student correctly identifies denaturation of the dehydrogenase enzymes and states that this prevents reduction of DCPIP. A more comprehensive answer would include 'so the solution remains blue' but this is enough for the second mark.

Full answer:

Dehydrogenase enzymes in the electron transfer chains are denatured by boiling (1) so cannot catalyse the reduction of DCPIP molecules (1) so the solution remains blue. (1)

Exam-style questions

- 1 a On the membranes of the disc-shaped structures inside chloroplasts. (1)
- b X is protons (1), Y is electrons (1), Z is reduced NADP. (1)
- c E is ATP synthase. (1)
- d Embedded across (1) the internal membranes of the chloroplasts. (1)
- e They are actively transported (1) by carrier proteins. (1)
- f They diffuse down (1) an electrochemical gradient. (1)
- 2 a X is water (1); Z is reduced NADP. (1)
- b Dehydrogenase enzymes (1) at the end of the electron transfer chains catalyse a reaction in which NADP molecules are reduced. (1)
- c Carbon dioxide is absorbed by the light-independent reaction (1) but oxygen is produced by the light-dependent reaction. (1)
- d When chlorophyll molecules absorb light, photo-ionisation releases electrons (1), which need to be replaced. (1) Photolysis of water provides electrons (1) that replace those lost by chlorophyll molecules in photo-ionisation.

Pages 93–96 Photosynthesis 2

Grade booster

- (a) Because respiration releases carbon dioxide (1)
- (b) Light intensity (1) and temperature (1)
- (c) The rate of photosynthesis increases at higher temperatures on the low light intensity curve (1) and at higher light intensities on the other two curves. (1)
- (d) Higher photosynthesis rate for leaves at higher temperature. (1) Inside leaves could be at 15 °C rather than 5 °C. (1) At high light intensity the extra carbon

dioxide uptake would be $2.45 - 1.4 = 1.05 \text{ mg g}^{-1} \text{ h}^{-1}$ (1)

- (e) Mark = 0 out of 2

Examiner comment: The student correctly identifies lack of light as a limiting factor but just says 'light' and has not specifically mentioned short day length and has not linked low rates of photosynthesis to slow production of organic substances for growth.

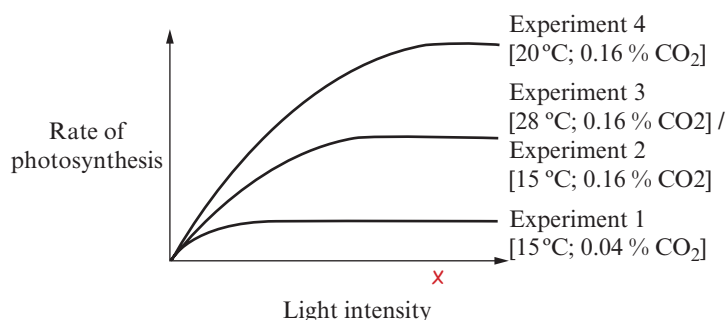
Full answer:

Photosynthesis is limited by a lack of light for much of the year because of short day length. (1) The rate of production of useful organic substances for growth is slow. (1)

Exam-style questions

- 1 a The fastest rate of photosynthesis was achieved at the optimum temperature for photosynthetic enzymes at 20 °C (1) and with an enriched carbon dioxide concentration of 0.16% so the light-independent reaction was not limited (1) by carbon dioxide concentration. At lower and higher temperatures either side of the optimum temperature, even with an enriched carbon dioxide concentration, the rate of photosynthesis was slower because enzyme activity was lower. (1) The rate was slowest at a temperature below the optimum, with normal atmospheric carbon dioxide concentration also limiting the rate of photosynthesis. (1)

b



Correct position of X (1)

- c This is the lowest (and therefore most economic) light intensity (1) that gives the maximum rate of photosynthesis at the optimum temperature of 20 °C and with an enriched carbon dioxide concentration of 0.16%. (1)

Pages 97–100 Respiration 1

Grade booster

- (a) There is a positive correlation between ATP / O ratio and body mass. (1)
- (b) The bull frog produces the most ATP relative to oxygen use. (1)
- (c) More oxygen use by the electron transfer chains means more electrons being transferred along them (1) from reduced coenzymes. This means more respiratory substrate is used to produce reduced coenzymes. (1)
- (d) Proton leakage would reduce the electrochemical gradient (1) built up by electron flow and proton transport, (1) resulting in less of a diffusion gradient for protons back through ATP synthase molecules. (1)
- (e) Mark = 0 out of 1

Examiner comment: The phospholipid bilayer does not contain fatty acid molecules, the phospholipid molecules

have fatty acid tails. An alternative answer is different/more carrier proteins in the membrane.

Full answer:

Phospholipids in the bilayer have different types of fatty acid tails/more unsaturated fatty acid tails. (1)

Exam-style questions

1 1 mark for each correct row:

	Glycolysis	Link reaction	Krebs cycle	
Occurs in mitochondrial matrix		✓	✓	(1)
Uses oxygen				(1)
Produces carbon dioxide		✓	✓	(1)
Reduces coenzymes	✓	✓	✓	(1)

- 2 a The use of carbohydrate as a respiratory substrate decreased and the use of lipid and amino acids increased. (1) The use of lipid increased faster during darkness than did amino acids. (1)
- b The use of lipid and amino acids decreased and use of carbohydrates sharply increased. (1)
- c In dark conditions when photosynthesis is prevented (1) and local stores of glucose/carbohydrate/starch are depleted (1) the tissues make use of alternative respiratory substrates.

Pages 101–104 Respiration 2

Grade booster

- (a) To the right (1)
- (b) A mixture of aerobic and anaerobic respiration. (1)
- (c) Draw two marks on the tube (1) and time the leading edge of the drop between one and the other. (1)
- (d) Mark = 0 out of 2

Examiner comment: This student does not appreciate that when aerobic respiration stops, net gas production will increase.

Full answer:

Aerobic respiration stopped as the oxygen ran out (1) so there was no more uptake of oxygen to offset increasing carbon dioxide volume. (1)

- (e) By converting the pyruvate from glycolysis into ethanol and CO₂ (1) the yeast cells were able to re-oxidise reduced NAD. (1)
- (f) The yeast cells ran out of respiratory substrate. (1)

Exam-style questions

- 1 a It is converted to lactate. (1)
- b Because if MPC activity is depleted, pyruvate will not enter the mitochondrial matrix (1) so activating PDH will have no effect on the altered route for pyruvate. (1)
- c Re-activating MPC could promote the transport of pyruvate into the mitochondrion (1) and divert it away from LDH. (1)
- 2 a The buffer controls the pH during the experiment (1) and the sucrose keeps the water potential the same

inside and outside the mitochondria (1) so they do not burst due to osmosis. (1)

- b The redox indicator changes colour when it is reduced by electrons from the electron transfer chain, (1) indicating that the electron transfer chain is functioning. (1)
- c These would normally be in the cytoplasm of the heart cells, which is lost when the mitochondria are isolated (1) and need to be supplied for the Krebs cycle to function. (1)

Pages 105–108 Energy and ecosystems

Grade booster

- (a) The units are kg m⁻¹ because the kelp plants grow along the rope in a line rather than growing across an area. (1)
- (b) Biomass represents the chemical energy store built up by the kelp at any point in time (1) minus respiratory losses. (1)
- (c) Net primary productivity is the rate of net primary production which is shown by the increase or decrease in biomass per metre between each month. From March to August, strain B shows higher productivity than strain A (1) whereas strain A shows higher productivity than strain B from September to November. (1) However, the graph doesn't indicate if the data are mean values so there is no indication of the uncertainty of the data (1) nor does it show SD bars so it is not possible to judge if any differences might be significant. (1)
- (d) Mark = 0 out of 2

Examiner comment: The answer does not specify that it is **abalone** faeces. Biological molecules cannot be lost as heat. The answer should say some biological molecules are used by **abalones** as respiratory substrate. Neither mark is gained.

Full answer:

Some of the biological molecules in kelp biomass are lost in abalone faeces (1) and some are used by abalones as respiratory substrate. (1)

- (e) Respiratory losses would be reduced because respiration would be slower in cooler water (1) so net production of abalones is higher.

Exam-style questions

- 1 a The total biomass of rice plants per square metre = 60 + 320 + 40 + 150 = 570 g. The stored chemical energy in this biomass = 570 × 23 141 = 13 190.4 kJ. (1) This was built up during a period of 105 days, so the net primary productivity = $\frac{13\,190.4}{105} = 125.6 \text{ kJ m}^{-2} \text{ day}^{-1}$ (1)
- b Yield is the biomass of the part of the plant that is harvested. The seeds in one square metre of rice have a biomass of 150 g and the total biomass is 570 g so the percentage yield is $\frac{150}{570} \times 100 = 26.3\%$ (1)
- c Biological molecules made during photosynthesis are transported in the phloem. (1) If plant hoppers feed on phloem sap, they take some of the biological molecules that would have formed seed biomass. (1)
- d Flowers provide food for other herbivores so the number of herbivores increases and the number of their predators increases. (1) The increased number of predators also feed on pest herbivores, reducing their numbers (1) and reducing the phloem sap that they remove, so a larger chemical energy store builds up in the rice seeds, which can be eaten by humans. (1)

Pages 109–112 Nutrient cycles

Grade booster

- (a) A mass of branching (1) threads (1) called hyphae.
 (b) To ensure that any radioactivity in the mycelium was transported from the plant roots. (1)

(c) $\frac{0.1}{3.9} \times 100 = 2.6\%$ (1)

- (d) Mark = 1 out of 2

Examiner comment: The student understands that the ^{14}C is incorporated into photosynthetic products but does not refer to transport in the phloem to the roots.

Full answer:

The $^{14}\text{CO}_2$ was used in photosynthesis (1) in the leaves. The ^{14}C was used to make organic substances that were translocated (1) to the roots and taken up by the fungus.

- (e) The organic substances gained from the plant supplement (1) those gained by saprobial nutrition. (1)

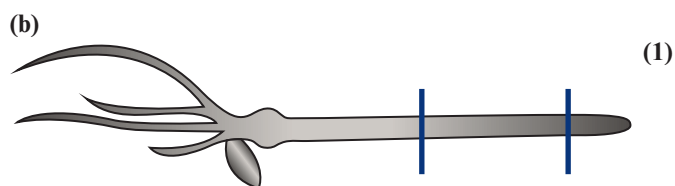
Exam-style questions

- 1 Fertilisers add soluble ions (1) such as ammonium ions, nitrate ions and phosphate ions to soil. Before they are taken up by plant roots, they may be leached (1) from the soil by heavy rain, which eventually drains into streams. (1) Here, nutrients encourage the growth of aquatic plants and algae, (1) some of which may die due to lack of light. (1) Decomposition of the dead material by saprobial bacteria can deplete the water of oxygen, (1) reducing the biodiversity of the stream community.
- 2 a Animals eat nitrogen in organic molecules in their food. Some of these molecules remain undigested in their faeces. Some nitrogen is excreted as urea in urine. (1) Undigested food molecules and urea molecules are decomposed by saprobial bacteria (1) leading to ammonification. Nitrogen in ammonium ions is returned to the soil. (1)
- b Nitrogen-fixing bacteria in the soil reduce nitrogen gas to ammonia. (1) Nitrogen-fixing bacteria use some of the resulting ammonium ions but some are used by the legumes. When the nitrogen-fixing bacteria or the legume dies, organic molecules are decomposed by saprobial bacteria, (1) leading to ammonification. Nitrogen in ammonium ions is returned to the soil. (1)

Pages 113–116 Survival and response

Grade booster

- (a) To provide a solution of the same water potential (1) as the shoot tissue to prevent cells swelling or shrinking due to osmosis, (1) which would change the length (1) of the segment.



It would have been cut out a little way back from the shoot tip, to include the zone of elongation but exclude the shoot tip which produces IAA. (1)

- (c) Length when IAA added = 10.4 mm
 Length after two hours = 12.0 mm (1)

$$\text{Percentage elongation} = \frac{(12.0 - 10.4)}{10} \times 100 = \frac{1.6}{10} \times 100 = 16\% \text{ (1)}$$

- (d) The IAA was supplied from the solution and was at an equal concentration in all parts of the segment (1) so cell elongation was the same in all parts of the segment. (1)
- (e) Mark = 3 out of 3

Examiner comment: This is a comprehensive answer, using appropriate terminology, which gains all 3 marks.

Full answer:

More IAA is transported towards the shaded side of the shoot. (1) IAA promotes shoot cell elongation, (1) so the cells on the shaded side grow more quickly than those on the lit side, (1) causing curvature towards the source of the light

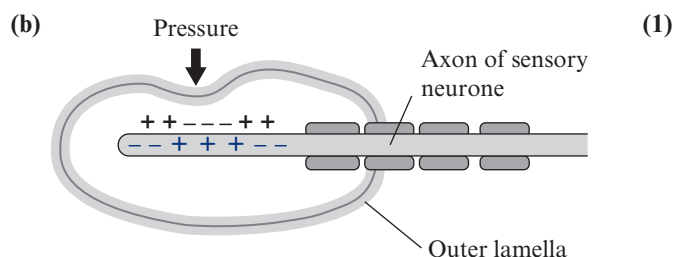
Exam-style questions

- 1 a Before the pulse, flies walked around randomly in the downwind part of the wind tunnel. (1) During the pulse, flies walked in a fairly straight line upwind. (1) After the pulse, the flies returned to walking around randomly, but turning more frequently. (1)
- b Chemotaxis (1) because the flies are showing a directional response to a chemical stimulus. (1)
- 2 Ensure the temperature and oxygen concentration (1) are the same in both choice chambers. Keep the choice chamber in darkened conditions. (1) Place a fish in the start chamber. (1) Allow it time to acclimatise. (1) Record how much time the fish spends in each chamber for a fixed time. (1)
- Repeat, using a new fish (1) each time.

Pages 117–120 Receptors

Grade booster

- (a) When the pressure is applied, a generator potential develops (1) but as the pressure continues, the generator potential subsides. (1) When the pressure is released, another generator potential develops and then subsides. (1)



- (c) Mark = 2 out of 3

Examiner comment: This is a good answer using information from the diagram and the correct term for the type of sodium ion channel, but it fails to use the term diffuse, implying active transport instead.

Full answer:

Distortion of the lamella causes the axon membrane underneath to be stretched. (1) Stretch-mediated sodium ions channels in this part of the membrane open. (1) Positively charged sodium ions **diffuse** into the axon. (1)

- (d) Even though the pressure stimulus continues (1), the axon membrane rapidly repolarises. (1)

Exam-style questions

- 1 a Up to a displacement of 104 pPa, the greater the distortion of the lamellae, the larger the generator potential. (1) Above 104 pPa, the generator potential does not increase any further. (1)
- b The membrane potential at B shows an all-or-nothing effect (1) compared to that at A, which, up to a certain point, is proportional (1) to the size of the stimulus.
- c A small pressure of 18 pPa does not result in a change in the membrane potential at B (1) so this is a below threshold stimulus. (1)
- 2 Chemoreceptors and pressure receptors (1) located in the aorta (1) close to the heart and in the carotid arteries (1) detect changes in blood pH and blood pressure. (1) An increase or decrease in the frequency of nerve impulses from these receptors stimulates either the cardiac acceleratory centre or inhibitory centre (1) in the medulla (1) of the brain.

Pages 121–124 Nerve impulses**Grade booster**

- (a) The data have been plotted on logarithmic paper (1) so that a large range of values can be included (1) on the same graph.
- (b) 40 ms^{-1} compared to 2 ms^{-1} (1)
- (c) Impulses are conducted in a saltatory pattern, (1) where the action potential can 'jump' from one node to the next, which is faster than moving smoothly (1) along the axon.
- (d) In both, the speed of conduction is positively correlated with axon diameter, (1) but speed increases as a different function of diameter (1) in myelinated compared with non-myelinated axons.
- (e) Mark = 0 out of 2

Examiner comment: The student does not understand that more cytoplasm means more ions are available to move towards the next node, depolarising it faster.

Full answer:

More ions in the axon allows for a greater movement of ions along it (1) so an action potential at one node pushes the next node to threshold more quickly. (1) This results in a higher impulse conduction.

Exam-style questions

- 1 The cell-surface membrane has carrier proteins (1) that actively transport sodium ions out of the axon and potassium ions into the axon. (1) For every three sodium ions transported out, two potassium ions are transported in. (1) The cell-surface membrane is also permeable to sodium ions and potassium ions via channel proteins, (1) more so to potassium ions. Both ions diffuse back down their concentration gradients, but more potassium ions diffuse back out. (1) The combined effect is to make the outside of the axon more positive (1) than the inside.
- 2 a At higher temperatures, diffusion occurs faster, (1) so when the sodium channels open, sodium ions diffuse into the axon faster, depolarising it faster (1) and when potassium channels open, potassium ions diffuse out faster, repolarising it faster. This means the action potential is shorter (1) and is able to push the next section of axon to threshold more quickly. (1)

- b The carrier proteins and the channel proteins will be denatured (1) so the resting potential will be lost and there will be no ion gradients (1) to drive action potentials.

Pages 125–128 Synaptic transmission
Grade booster

- (a) Action potentials (1) occurring at the synaptic knob.
- (b) Synaptic vesicles move to and fuse with (1) the pre-synaptic membrane. (1)
- (c) Calcium ions are actively transported (1) out of the synaptic knob by carrier proteins. (1)
- (d) Mark = 1 out of 3

Examiner comment: The student does not refer to shape changes in either protein molecule. The answer should contain the idea that receptor protein shape change has a knock-on effect on the shape of channel proteins beside them. A better answer would also refer to acetylcholine molecules.

Full answer:

Acetylcholine molecules (1) bind to receptor proteins that change shape (1) and cause a shape change in adjacent sodium ion channels (1), opening them.

- (e) Neuromuscular junctions have a greater density of acetylcholine receptors (1) on the post-synaptic membrane compared to cholinergic synapses. This means that pre-synaptic action potentials are more likely (1) to lead to muscle contraction.
- (f) Cogentin blocks cholinergic receptors, preventing acetylcholine from binding (1) so in neuromuscular junctions, it would inhibit muscle contraction and reduce muscle stiffness. (1)

Exam-style questions

- 1 a Q = myelin, R = end-plate; (1) S = mitochondrion, T = vesicle; (1) U = synaptic cleft, V = post-synaptic membrane. (1)
- b The post-synaptic membrane is folded, (1) which increases the surface area and allows space for more acetylcholine receptor molecules. (1)
- c The neurotoxin molecules linked to the fluorescent molecules bind to acetylcholine receptor molecules. (1) The fluorescent points can be seen using an optical microscope. The number in a certain area can be counted. (1)
- 2 Cholinesterase breaks down acetylcholine in synapses. (1) If acetylcholine breakdown is inhibited, more acetylcholine molecules will be present (1) in neuromuscular junctions. This will compensate for the reduced number of working acetylcholine receptor molecules. (1) It means the maximum possible number of acetylcholine receptor molecules are activated (1) helping to improve muscle contraction. (1)

Pages 129–132 Skeletal muscle**Grade booster**

- (a) Tropomyosin molecules (1) block actin binding sites preventing actinomyosin bridge formation. (1)
- (b) Calcium ions are released (1) into the muscle fibre cytoplasm that causes tropomyosin molecules to move out of the way (1) of actin binding sites.

- (c) ATP hydrolysis occurs in another part of the cycle. (1)
The power stroke only involves the release of an inorganic phosphate group. (1)

- (d) On binding to actin, (1) they change shape (1) so the heads attached to the actin filaments move position.

- (e) Marks = 1 out of 2

Examiner comment: There are two pieces of information in the diagram relating to ATP. ATP is also shown binding to allow bridge detachment.

Full answer:

ATP binding to the myosin head is required for bridge detachment (1) and ATP hydrolysis is required to reset the shape (1) of the myosin molecule ready for the next cycle.

Exam-style questions

- 1 a Different myofibrils will be different lengths. (1) Using a sarcomere standardises the starting length. (1)
- b $2.75\mu\text{m}$ (1)
- c Percentage increase is $95 - 60 = 35\%$ (1)
 $600 \times \frac{35}{100} = 210\mu\text{N}$ (1)
- d When sarcomeres are stretched beyond $3\mu\text{m}$, the length of overlap between the thick and thin filaments is decreased. (1) Fewer actinomyosin bridges can form and the force generated by the remaining bridges is reduced. (1)
- 2 a Calibrate an eyepiece graticule (1) for the objective lens being used. Measure the diameter with the graticule. Convert graticule units to diameter. (1)
- b Muscle fibre X is stained darker which indicates it has more SDH and therefore more mitochondria. (1) Slow fibres have more mitochondria than fast fibres. (1)
- c Fast fibres work suddenly (1) in rapid bursts and use phosphocreatine to supply ATP (1) for the first few seconds of work until more ATP can be made by respiration.

Pages 133–136 Homeostasis and blood glucose control

Grade booster

- (a) Glucose concentration rises to a peak during the first hour as carbohydrate is digested and glucose absorbed. (1)
Glucose concentration then falls as it is taken up and used in respiration by all body cells. (1) Most of the glucose is stored as glycogen in the liver and in skeletal muscle fibres. (1)
- (b) Glucagon concentration falls rapidly and remains low. (1)
Insulin concentration rises rapidly to a peak during the first hour (1) and then falls more slowly. (1)
- (c) Mark = 3 out of 3
Examiner comment: A good answer that spots glucagon concentration rising before the meal is linked to glucose concentration falling.
Full answer:
Glucagon concentration is high and increasing (1) before the meal because blood glucose concentration is low and falling. (1) Glucagon acts to increase blood glucose concentration. (1)
- (d) Insulin concentration increases because blood glucose concentration increases. (1) Insulin acts to decrease blood glucose concentration. (1)

- (e) Two separate mechanisms mean blood glucose concentration can be controlled more tightly. (1)

Exam-style questions

- 1 Enzymes inside and outside cells require a stable pH (1) and temperature (1) to maintain efficient activity (1) for metabolism. Cells require a stable water potential to avoid swelling or shrinking and possible damage due to osmosis. (1) Cells also require a stable blood glucose concentration to provide an adequate supply of respiratory substrate. (1)
- 2 The hypothalamus and pituitary gland (1) stimulate the production of testosterone. (1) As testosterone concentration increases, it feeds back to the hypothalamus and pituitary gland, (1) reducing their production of GnRH and LH/FSH (1) so the testes produce less testosterone. (1)

Pages 137–140 Blood glucose control and diabetes

Grade booster

- (a)

Urine sample	Repeat absorbance readings			Mean absorbance	Glucose concentration / mol dm^{-3}
A	1.07	1.03	1.06	1.05	4.6
B	0.60	0.60	0.40	0.53	1.1
C	1.25	1.28	1.22	1.25	7.5

(1)

(1)

- (b) Mark = 1 out of 2

Examiner comment: The temperature of the water bath for the Benedict's test is not a factor that needs to be controlled as long as it is above 90°C so that the test works.

Full answer:

Same volume of each sample used (1) as was used for the calibration curve tests.

Left for same time in the water bath for each test. (1)

- (c) A high blood glucose concentration (1) that cannot all be reabsorbed after filtration by the kidneys. (1)
- (d) A red filter (1) is the most suitable for measuring the absorbance of blue Benedict's solution (1) after it has reacted with glucose and the precipitate has settled.

Exam-style questions

- 1 Different target cells have different receptor proteins (1) on their cell-surface membranes that have binding sites (1) specific for either glucagon or adrenaline. (1) So although the internal second messenger is the same, it is produced in response to signalling from different hormones (1).
- 2 The risk factors for the increasing incidence of Type II diabetes are a lack of exercise and a diet containing a high proportion of sugary food and drinks. (1) Health advisers support compulsory labelling of food (1) to include warnings about high sugar content and the idea of a sugar tax (1) on such products to deter people from buying them. The food industry argues that people just need educating about the causes (1) so they can choose (1)

to avoid sugary products and to exercise more. They say that it would be too costly for them to include compulsory warnings on products **(1)** or to be forced to remove such products from the market. **(5 max)**

Pages 141–144 Control of blood water potential

Grade booster

- Osmoregulation **(1)**
- A decrease **(1)** in blood water potential.
- X is the hypothalamus **(1)** in the brain. **(1)**
- ADH increases the permeability **(1)** of the collecting ducts and distal convoluted tubules to water **(1)**, so more water is absorbed from the filtrate by osmosis. **(1)**

- Mark = 3 out of 3

Examiner comment: A good answer that includes all the necessary details to describe the negative feedback. The student understands the involvement of the nervous system in this control system.

Full answer:

Osmoreceptors in the hypothalamus **(1)** detect that the water potential of the blood has become less negative **(1)** as a result of the urine becoming more concentrated and less water being excreted. The hypothalamus reduces its stimulation of the posterior pituitary gland. **(1)**

- Sodium ions continue to be excreted in the urine **(1)** but water is continuously reabsorbed **(1)** into the plasma when it is not necessary. This means that the blood becomes diluted. **(1)**

Exam-style questions

- Hormones travel to their target cells in the blood **(1)** and bind to specific receptor proteins **(1)** on the surface of target cells. This means their responses can be widespread, **(1)** but tend to be slower and last for longer. **(1)** Nerve impulses travel directly to target cells along neurons **(1)** that release chemical messengers **(1)** onto the target cells. This means their responses are localised **(1)** but tend to be fast and short-lived. **(1) (6 max)**
- Bowman's capsule **(1)**
 - Glucose is filtered at the Bowman's capsule **(1)** but then fully reabsorbed in the proximal convoluted tubule, so there is no glucose in the urine. **(1)**
 - Sodium ions are filtered at the Bowman's capsule **(1)** and partially reabsorbed by the loop of Henle **(1)** depending on how much water is being reabsorbed, so there are fewer sodium ions in the urine. **(1)**

Pages 145–148 Inheritance

Grade booster

- HhPp **(1)**
- These plants would be short with green stems. **(1)**
- 9:3:3:1 normal height purple : normal height green : short purple : short green. **(1)** This is the expected dihybrid ratio if the B and H alleles are dominant. **(1)**

- Mark = 1 out of 3

Examiner comment: The student recognises that the calculated value is lower than the critical value but misinterprets the use of the statistical test for this situation

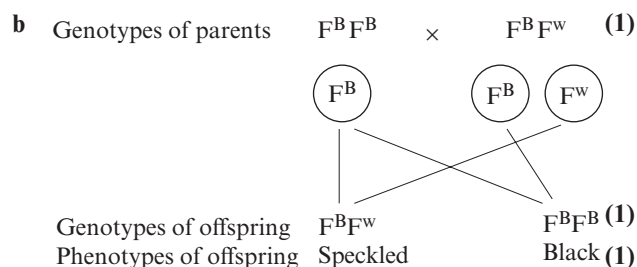
and simply says 'the results' rather than saying exactly what is significant or not. In genetic crosses, a good fit between the observed and expected ratios is indicated when the calculated value is lower than the critical value.

Full answer:

The calculated chi-squared value is lower than the critical value **(1)** so there is no significant difference **(1)** between the observed and the predicted ratios **(1)** of phenotypes.

Exam-style questions

- Codominance **(1)** because both alleles are expressed in the feathers giving patches **(1)** of black and white colour.



- The predicted ratio for the second cross is 1:1:1:1. **(1)** However, very few of the offspring had the genotypes Yyss or yySs **(1)** so most of the gametes produced by the YySs plants must have been YS and ys. **(1)** This means YS and ys are linked **(1)** by having loci close together on the same chromosome, reducing the chance of crossing over occurring **(1)** between them.

Pages 149–152 Populations and Speciation 1

Grade booster

- This is genetic variation **(1)** because it is caused by a mutation. **(1)**
- Mark = 1 out of 2

Examiner comment: The working is correct but the question asks for percentages and the student gives no clear indication of the final answers.

Full answer:

$$p^2 + 2pq + q^2 = 1$$

$$\text{Carrier frequency} = 2pq$$

- In Han Chinese, $q = 0.09$ and $p = 1 - q = 0.91$

$$2pq = 2 \times 0.09 \times 0.91 = 0.16$$

16% of Han Chinese people are carriers. **(1)**

- In Tibetans, $q = 0.87$ and $p = 1 - q = 0.13$

$$2pq = 2 \times 0.87 \times 0.13 = 0.23$$

23% of Tibetans are carriers. **(1)**

- In Tibetan people living at high altitude, the aa genotype is advantageous **(1)** so its frequency has increased. **(1)** This means the a allele is more likely to be passed on so there are more carriers, **(1)** even though the carriers are not at an advantage

Exam-style questions

- Mutations can result in the appearance of new phenotypes by introducing new alleles to the gene pool **(1)**. Independent segregation of homologous chromosomes **(1)** or crossing over between homologous chromosomes **(1)** can result in different genotypes in

gametes. (1) Random fertilisation between gametes with different genotypes (1) can result in different phenotypes in a population.

- 2 a 20% at 42°N and 80% at 38°N. (1)
 b At 38°N the water is warmer (1) so the LDH-a allele is advantageous (1) so its frequency has increased compared to 42°N.
 c Global warming could result in the frequency of the allele increasing at all latitudes. (1)

Pages 153–156 Populations and Speciation 2

Grade booster

- (a) A gene pool consists of all the alleles (1) of all genes present in a population (1) at any given time.
 (b) Mark = 1 out of 2

Examiner comment: The student does not indicate that this will only happen if there are different conditions in different parts of the habitat.

Full answer:

Two advantageous phenotypes present in the same population may both be selected for (1) at the same time if conditions across the habitat vary. (1)

- (c) Originally, one population (1) of palm trees grew on both soil types at both altitudes. A mutation resulted in a different flowering time, (1) which was an advantage on one of the soil conditions. Disruptive selection (1) favoured one phenotype at each altitude. Eventually, sufficient differences accumulated in the gene pools (1) of the two groups that they could not form fertile offspring. (1)
 (d) The palms are able to flower before their growth becomes nutrient limited. (1)
 (e) The groups of palms with different flowering times overlap in their distribution. (1)

Exam-style questions

- 1 Interspecific competition (1) between species for food or predation (1) and disease (1) means that individuals with advantageous phenotypes are more likely to survive. (1) Intraspecific competition (1) for mates or territory or nesting space means that individuals with advantageous phenotypes are more likely to reproduce or reproduce more successfully. (1)
 2 In very small populations, (1) the small number of individuals that reproduce pass on only some of the alleles (1) in the gene pool. This means that allele frequencies can fluctuate by chance (1) as the breeding individuals pass on a random sample from the gene pool each generation. (1)

Pages 157–160 Populations in ecosystems 1

Grade booster

- (a) When the hen harrier population increased, the grouse population declined. (1) The grouse population also increased in years when the hen harrier population remained low. (1) But when the hen harrier population fell, the grouse population also continued to fall (1) so other factors may affect the grouse population. (1)

- (b) Mark = 0 out of 4

Examiner comment: The student does not include valid scientific or economic points. The student should form a balanced explanation based on the underlying science and the impact of conservation on the rural economy, rather than taking the side of conservationists and asserting a value-based explanation.

Full answer:

Hen harriers could reduce grouse populations until hunting is not viable. (1) Hunting provides rural employment and supports local businesses. (1) However, illegal killing of hen harriers threatens their survival in the UK (1) and the data about the effect of hen harriers are not conclusive. (1)

- (c) Data about the effects of other possible predators (1) and other factors that may reduce the grouse population, such as bad winters or disease. (1)

Exam-style questions

- 1 Succession occurs on sand dunes where low growing flowering plants are outcompeted, first by grasses (1) and then by taller shrubs (1) and finally trees. The rare plants of conservation value are low growing so would be outcompeted. (1) Sheep eat grass and young shrubs, (1) preventing the progress of the succession and so protecting the rare plants from competition. (1)
 2 Reeds trap sediment (1) making the deeper water shallower and suitable for them to colonise further. (1) The reeds gradually encroach (1) on the open water, until they fill the whole space and there are no open areas or reed bed edges. (1)

Pages 161–164 Populations in ecosystems 2

Grade booster

- (a) Each count was for five 4 m² quadrats, which is 20 m². So the total number of grasshoppers in five quadrats (1) was divided by 20 (1) to give the number per square metre that is presented on the bar chart.

- (b) Mark = 0 out of 2

Examiner comment: The student does not compare the numbers to the control samples at each site.

Full answer:

Grass grazed by cattle has far fewer grasshoppers per square metre than the control areas (1) at the same sites. Grass grazed by sheep has more grasshoppers per square metre than the control areas (1) at the same sites.

- (c) Sheep grazing provides a suitable mixture of grass heights. Patches of shorter grass provide sunlight and higher temperatures, (1) while patches of longer grass provide protection (1) from predators.
 (d) The temperature in the grass (1) is an abiotic factor and predation (1) is a biotic factor.

Exam-style questions

- 1 Capture a sample of water voles from the new population. Mark them in such a way that the mark is not removed by them swimming in water (1) and release them. (1) Allow sufficient time for the marked water voles to disperse in the population before capturing a second

sample. (1) Number surviving = (number captured and marked in first sample $\times$ number in second sample) / number recaptured by second sample (1)

- 2 a Plot the data on a scattergram. (1)
- b The statistical test indicates a significant (1) positive correlation (1) between water speed and the number of stonefly larvae per square metre. The probability that this correlation could have occurred by chance is less than 5%. (1)
- c Water speed is a factor determining the distribution of stonefly larvae. (1)

Pages 165–168 Gene expression

Grade booster

- (a) The ATM enzyme will have a different shape (1) so will be unable to bind to broken DNA. (1)

- (b) Mark = 1 out of 2

Examiner comment: The student correctly predicts the effect but does not explain their answer so does not gain the second mark.

Full answer:

RA T cells will divide before DNA is repaired (1) because translation of the tumour suppressor gene is not effective. (1)

- (c) DNA damage will accumulate (1) in RA T cells because they will divide before breaks in the DNA are repaired. (1)
- (d) T cells are involved in detecting abnormal body cells. (1) If T cell function is impaired, tumour cells may remain undetected and divide uncontrollably. (1)
- (e) Cigarette smoke contains mutagenic agents (1) that damage DNA and could accelerate the rate of accumulation of DNA damage. (1)

Exam-style questions

- 1 Oncogenes are mutated alleles (1) of genes that control cell division. (1) The mutant allele stimulates cells to divide by mitosis too quickly. (1) Oncogenes can cause tumours. Tumour suppressor genes slow cell division (1) by inhibiting the expression of genes that control cell division. (1) In normal cells they regulate the cell cycle. Mutated or methylated tumour suppressor genes allow the rate of mitosis to increase. (1)
- 2 a The process shows acetylation (1) of the histone proteins (1) supporting the DNA in a chromosome. Acetylation alters the interaction between histone molecules allowing the DNA to become less tightly packed. (1)
- b Histones are found only in the chromosomes of eukaryotic cells. (1)
- c If DNA is less tightly packed, the increased access (1) to the strands allows transcription (1) and expression of genes that were previously suppressed. (1)

Pages 169–172 Gene technology

Grade booster

- (a) They were acting as DNA probes. (1)
- (b) They were made either radioactive or fluorescent (1) because they would not otherwise be visible (1) on the electrophoresis gel.
- (c) By using a gene machine (1), which builds a short sequence of DNA.

- (d) A Taq 1 restriction site was found to be missing. (1) A restriction site is a known sequence of bases where a restriction enzyme cuts DNA. (1) Knowing the sequence of the Taq 1 enabled the change to be predicted. (1)

- (e) It has a sequence of bases complementary (1) to part of the mutant allele so it binds to those fragments that contain the mutant allele (1) and produces a visible spot on the gel. (1)

- (f) Mark = 1 out of 2

Examiner comment: The student only gives one side of the evaluation. For 2 marks, one point for and one point against is required.

Full answer:

Parents are able to know the health of the developing foetus with certainty, (1) especially if there is a family history of the disease. However, the results of screening can require difficult decisions about allowing the pregnancy to continue. (1) DNA polymerase (1) creates another identical DNA strand from the original single strand of DNA. (1)

Exam-style questions

- 1 Many genes are common to all organisms, (1) so knowing their effects could contribute to understanding why human gene expression and protein function sometimes fail to work correctly. (1) However, since so many have been sequenced already, additional eukaryote genomes may not reveal much more information useful to humans. (1) Also, eukaryote genomes are much less useful for identification of potential antigens for use in vaccine production (1) since disease-causing organisms are predominantly prokaryotes. (1)
- 2 Three from:
- Restriction endonucleases (1) are used to cut DNA into fragments. (1)
 - Ligases (1) are used to join (1) fragments of DNA.
 - Reverse transcriptase (1) is used convert mRNA to fragments of DNA. (1)
 - DNA polymerase (1) creates another identical DNA strand from the original single strand of DNA during PCR. (1)

Paper 1

Grade booster

- 1 (a) Antibodies are specific for a particular antigen because their binding sites (1) have a shape that is complementary to the shape (1) of the antigen molecule.
- (b) Tissue fluid leaks from capillaries. (1) Contraction of the ventricles of the heart (1) generates hydrostatic pressure (1) in the capillaries that forces tissue fluid out between the capillary cells. (1)
- (c) Magacizumab molecules bind to LRG1 molecules (1) and prevent them binding to protein receptors (1) on capillary cells.
- (d) Monoclonal antibodies rely on the use of mice for their production and Magacizumab was tested on other animals. (1) Some people are opposed to the use of animals for medical research. (1)

Guided questions

- 2 (a) How many branches there are in a certain volume. (1)
 (b) Amylase will shorten the linear chains (1) and provide maltose molecules that can be used to form new branches. (1)
 (c) Starch is hydrolysed by amylase to form maltose. (1) Maltose is then hydrolysed by **membrane-bound maltase/disaccharidase** (1) to form glucose. (1)
 (d) SDS is digested more slowly than normal starch. (1)
 (e) Amylase cannot hydrolyse the glycosidic bonds at branch points. (1) Other enzymes are needed (1) to do this, which slows down the rate of digestion.

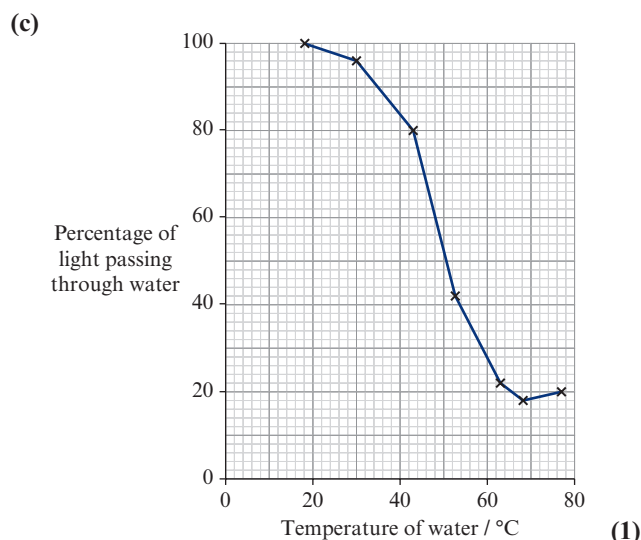
- 3 (a) In trehalose, one glucose molecule is inverted. (1)
 (b) By cells lining the ileum. (1) because trehalose is a disaccharide and membrane-bound disaccharidases are found on the cell-surface membranes of cells lining the ileum. (1)
 (c) People with no trehalase cannot hydrolyse trehalose (1) to glucose so it cannot be absorbed. It passes into the large intestine where it reduces the water potential. (1) Water is drawn into the large intestine by **osmosis** (1) causing diarrhoea.
 (d) A mutation has arisen giving a pathogenic strain the ability to grow on a very low concentration of trehalose. (1) If processed foods are being eaten and traces of trehalose reach the large intestine the mutant strain is at an advantage. (1) Other strains cannot survive but the mutant pathogenic strain grows and reproduces and passes on its alleles. (1)

- 4 Passive immunity is achieved by giving a person some antibodies from another source. (1) Active immunity involves provoking an immune response so that the person's plasma cells produce their own antibodies. (1) Passive immunity does not last as long as active immunity. In passive immunity, the antibodies are broken down relatively quickly. (1) In active immunity, memory cells retain the ability to produce more antibodies for much longer. (1) Passive immunity is achieved immediately on injection of the antibodies (1) but active immunity takes a while to be effective because it takes time to produce the antibodies. (1)

- 5 (a) The number of lamellae (1) per millimetre of gill filament. (1)
 (b) The mean gill area does not seem to relate to frequency of lamellae. (1) Because it is not standardised by mass, it could vary according to the size of the fish. This means that the gill areas are not comparable. (1)
 (c) A more active fish does more aerobic respiration, (1) requiring more oxygen. The active fish has the highest frequency of lamellae, which correlates with a higher demand for oxygen. (1) The sluggish species have a lower frequency of lamellae, which correlates with a lower demand for oxygen. (1)
 (d) Running water has a higher concentration of oxygen. Species B has the lowest frequency of lamellae (1) but this could be compensated for by having water containing more oxygen (1) flowing across the gills.
 (e) mass-specific gill area for species B = $\frac{22.9}{25} = 0.916$
 mass-specific gill area for species C = $\frac{91.4}{37} = 2.47$ (1)
 Ratio = $2.47 : 0.916 = 1 : 0.37$ (1)

- 6 Controlling weeds reduces the number of plant species (1) in the landscape which reduces the range of food available for insects, so the number of insect species (1) and their predators (1) is also reduced. Using pesticides to control pests may also reduce the number of non-pest species (1) if they are susceptible to the pesticide. The use of inorganic fertilisers may lead to eutrophication of ditches and streams, which can eventually result in the loss of species intolerant of oxygen depletion. (1)

- 7 (a) The time they left the plant before finding the rubidium ion concentration in the dried leaf tissue. (1)
 (b) Plant tissue can contain different amounts of water so the rubidium ion uptake would not be standardised if they used wet tissue. (1)
 (c) The scale is a $\log_{10}$ scale (1) because there is a large range of rates to accommodate on the same axis. (1)
 (d) The rate reaches a plateau on the graph. This suggests that the uptake is active (1) and that the carrier proteins have become saturated. (1) The effect of the inhibitor supports this because active uptake requires the hydrolysis of ATP. (1)
 (e) Phosphate ions are used to make ATP. (1)
- 8 (a) The cylinders should all be cut to the same length (1).
 (b) The cylinders were rinsed to remove any pigment already on the outside after cutting. (1)



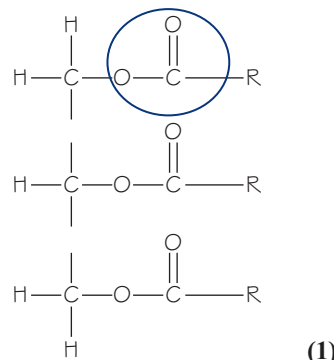
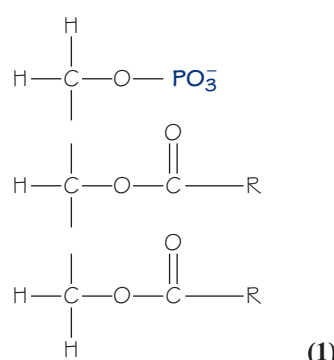
- (d) The temperature of thermostatically controlled water baths varies and the students recorded actual temperatures of the water during the experiment. (1)
 (e) The higher the temperature, the more pigment moves out of the beetroot cells. (1) This is because temperature denatures carrier proteins, (1) opening up gaps in the membrane (1) through which pigment molecules can leak.
- 9 (a) RCOOH (1)
 (b) A has a carbon-carbon double bond (1) and two fewer hydrogen atoms. (1)
 (c) Tick in box 3. (Fatty acid B is found in triglycerides but fatty acid A is not.) (1)
 (d) If the percentage of fatty acids of the form shown in B is increased in the diet, the concentration of LDL in the blood increases and the concentration of HDL decreases. (1) This means the ratio of LDL to HDL increases, (1) increasing the risk of cardiovascular disease. (1)

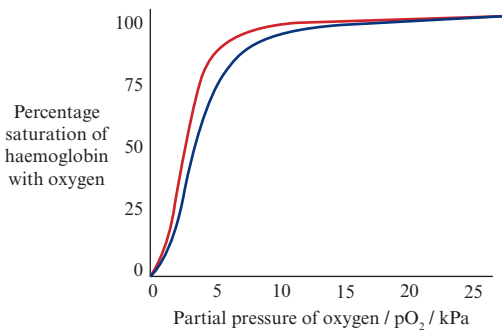
- 10 Collect a large number of seeds from each group of trees to ensure the sample is representative. (1) Make sure these seeds are collected randomly (1) from different heights and on different sides of different trees in each group. Measure the length of each seed and calculate the mean length (1) for each group of seeds. Find the standard deviation of the mean for each group of seeds to evaluate the dispersion (1) of the data. Use a *t*-test to find out if the mean values are significantly different to one another. (1)
- 11 (a) A scanning electron microscope (1) because the cells are visible in three dimensions / only the outside surface can be seen. (1)
- (b) Magnification = $\frac{\text{size of image in mm} \times 1000}{\text{size of real object}}$
 $= \frac{5500}{4} = \times 1375$ (2)
- (c) The cell vacuole (1)
- (d) Mitosis (1)
- (e) Lipids and phospholipids (1)

Exam-style questions

- 12 a Same area of substrate sampled with the net each time. (1)
- b The species richness is 7. (1)
- c $N(N-1) = 81(81-1) = 6480$
 $Sn(n-1) = 4(4-1) + 3(3-1) + 4(4-1) + 6(6-1) + 28(28-1) + 22(22-1) + 14(14-1) = 1460$ (1)
 $d = \frac{6480}{1460} = 4.44$ (2)
- d The community at site B contains fewer species compared to site A. (1) The community at site A has a more even abundance of the species present compared to site B. (1)
- e Use of fertiliser on arable fields results in run-off into the stream. (1) Excess nitrates in the stream are harmful to most aquatic organisms. (1) Only a few species are able to survive. (1)
- 13 a 4 dm^3 inhaled in 3 seconds so rate = $\frac{4}{3} = 1.33\text{ dm}^3\text{ s}^{-1}$ (1)
- b Diaphragm (1) and external intercostal muscles (1)
- c 3 breathing cycles in 15 seconds so breathing rate = $\frac{60}{15} \times 3 = 12\text{ min}^{-1}$ (1)
Tidal volume = 1.1 dm^3 so PVR = $1.1 \times 12 = 13.2\text{ dm}^3\text{ min}^{-1}$ (1)
- d The volume of air remaining in the lungs is higher after exhalation (1) during normal breathing, so the oxygen in inhaled air is diluted more by used air with a lower oxygen concentration. (1)
- e Oxygen **diffuses** down a concentration gradient (1) across the alveolar epithelium (1) and then across the capillary epithelium. (1)
- 14 a During the dry season the xylem tension becomes steadily more negative. (1) During the wet season the xylem tension becomes less negative. (1) This happens more slowly, towards the end of the wet season. (1)
- b The difference between the end of the dry season and the start of the wet season is not likely to be significant because the SD bars overlap. (1) The difference between the end of the dry season and the end of the wet season is likely to be significant because the SD bars do not overlap. (1)
- c Water is pulled up xylem vessels by transpiration. (1) Water molecules are polar and attract one another. (1)

When the water in xylem is pulled, the pressure inside falls below atmospheric pressure. (1)

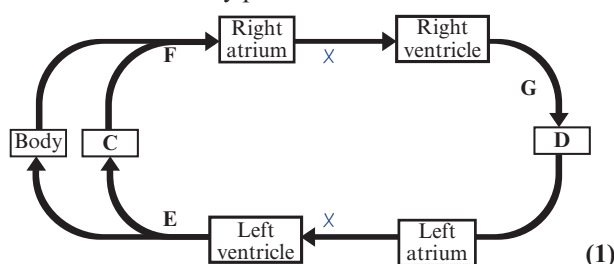
- d The soil is dry (1) so water moves less rapidly into the roots to replace water lost during transpiration. (1)
- 15 Water is lost from the mesophyll cells in the leaf by transpiration. (1) This lowers the water potential of the mesophyll cells. (1) Water moves into the mesophyll cells by osmosis, pulling more water up the xylem vessels. (1) Water molecules cohere due to hydrogen bonds (1) so the whole column of water (1) in the xylem vessels is pulled under tension.
- 16 a Endopeptidases are enzymes that hydrolyse peptide bonds within the length of the polypeptide. (1)
- b Endopeptidases reduce polypeptides to shorter peptide chains, (1) providing more chain ends for exopeptidases to work on. (1)
- c Because they are not fragmented by endopeptidases to provide more ends, (1) exopeptidases can only hydrolyse these longer peptide chains slowly. (1)
- d If the bacterial endopeptidase is able to hydrolyse peptide bonds within the resistant peptide chains to give shorter peptide chains, (1) the shorter chains could then be hydrolysed much more quickly by human exopeptidases. (1)
- 17 a Triglyceride (1)
- b
- 
- (1)
- c
- 
- (1)
- d A triglyceride is completely hydrophobic (1) but the phosphate-containing group of the phospholipid is hydrophilic (1) and the fatty acids are hydrophobic. (1)
- e The phospholipids arrange themselves into two layers (1) so that the hydrophilic heads point outwards in contact with the water-based surroundings. (1) and the hydrophilic tails point inwards away from the water-based surroundings. (1)
- 18 a Labelled organic substances made by photosynthesis are transported in the phloem (1) and the radioactive label could not pass the rings to the shoot tip or root tip. (1)

- b It killed phloem cells, which are near the surface of the stem and that rely on metabolic activity to function. (1)
- c Ions are transported with water in the xylem, (1) which does not rely on metabolic activity to function. (1)
- d The radioactivity from radioactive ions could not be distinguished from the radioactivity from labelled organic substances. (1)
- 19 a A = metaphase, B = anaphase, C = telophase, (1, for all of A—C correct) D = interphase (1)
- b The stain is selective for DNA (1) so makes chromosomes more visible (1) against the rest of the cell.
- c The impact spreads out the root tip tissue into a thin layer of cells. (1)
- d $7.3 \times 4.1 \times 10^{-3} = 0.02993 \text{ mm} = 29.9 \mu\text{m}$ (1)
- e The calibration of the eyepiece graticule would be different. (1)
- 20 a By facilitated diffusion, (1) because the concentration of ions in the cells reaches a plateau indicating equilibration. (1) However, ions cannot cross cell membranes by simple diffusion so carrier proteins or channel proteins must be involved. (1)
- b 160 arbitrary units (1)
- c Without inhibitor, the concentration of ions in the cells continues to climb above the external concentration and against the concentration gradient. (1) When respiration was stopped so there was no ATP available, the transport was limited. (1)
- d Difference after one hour is 200 extra arbitrary units. (1)
So additional mean rate = $\frac{200}{60} = 3.33 \text{ arbitrary units min}^{-1}$. (1)
- 21 a W is the active site. (1) Y is an enzyme-substrate complex. (1)
- b Each colour represents a different polypeptide chain. (1)
- c It lowers the activation energy (1) for the phosphorylation reaction by stressing bonds in the substrate. (1)
- d The monosaccharides must all have a very **similar** shape, (1) complementary (1) to the active site.
- e Before the glucose binds, the active site is not complementary (1) to the shape of the glucose. The shape of the active site is changed by the formation of the enzyme-substrate complex. (1)
- 22 a A phylogenetic classification organises species on the basis of their evolutionary relationships. (1)
- b A hierarchy is a series of smaller groups placed within larger groups, (1) with no overlap between the groups. (1)
- c Family (1)
- d *Dendroica* (1)
- e It is important in courtship (1) to ensure that they only mate with the same species. (1)
- f The mRNA molecules for a protein common to all the species being investigated are isolated. (1) The base sequence of all the mRNA molecules is determined. (1) Differences in the base sequence are counted. The more differences there are, the less closely two species are related. (1)
- 23 a Antibiotics are delivered in the blood and the bacteria are in the alveoli so the antibiotic molecules have to cross the capillary epithelium (1) and the alveolar epithelium (1) to reach bacteria.
- b Different antibiotics target the different groups of bacteria (1) so there are more opportunities for alleles for resistance to become advantageous. (1)
- c The longer the treatment time, the more chance there is of mutations for resistance occurring. (1) There is also a greater risk that the person taking the antibiotics will not comply with the instructions for taking the drug, allowing some bacteria to survive. (1)
- d Random mutation can result in alleles for antibiotic resistance occurring. (1) In groups of bacteria exposed to INH or RIF, (1) an allele for resistance gives those individuals an advantage. (1) They divide and pass on the resistance allele to the next generation of bacteria (1) while all the other bacteria die.
- 24 a 55% saturated (1)
- b Inhaled air is mixed with some air left in the lungs from the previous breath, which has a different partial pressure of oxygen. (1)
- c Up to four oxygen molecules can bind to haemoglobin molecules. (1) The first oxygen to bind causes a change in shape of the molecules that makes it easier for the next one to bind. (1) The same happens for the second and third oxygen. (1) This cooperative binding causes the increasing gradient, but, as the haemoglobin molecules become saturated, the curve flattens off. (1)
- d
- 
- Percentage saturation of haemoglobin with oxygen
- Partial pressure of oxygen / pO_2 / kPa (1)
- e Foetal haemoglobin has a higher affinity for oxygen than adult haemoglobin (1) so the curve is positioned to the left. (1)
- 25 Carbon dioxide diffuses (1) down a concentration gradient (1) from the atmosphere into the leaf airspaces (1) through stomata (1) and into mesophyll cells. Oxygen diffuses down a concentration gradient from the mesophyll cells (1) into the airspaces and then through stomata into the atmosphere.
- 26 a Translation (1)
- b X is an amino acid; (1) Y is a tRNA. (1)
- c tRNA molecules are relatively short molecules (1) that are folded back on themselves to form a complex shape (1) held in place by hydrogen bonds between complementary bases. (1)
- d Anti-codon (1)
- e GAG (1)
- f glycine-valine-leucine-aspartic (1) acid-isoleucine (1)
- 27 a The pale blue biuret solution (1) would turn violet (1) in the gelatin solution.
- b To create a range of pH, because this was the factor being investigated. (1)

- c Different shades/intensities of violet (1) because different amounts of gelatin would have been hydrolysed in the time allowed so different concentrations would remain (1) in the test tubes.
- d Set up a dilution series (1) of gelatin solutions. Test each one with the **same volume** of biuret solution. (1) Measure the absorbances after each test. (1) Plot a graph of absorbance against gelatin concentration. (1)
- e Read off the concentrations for the absorbance at each pH from the curve. (1) Find the pH giving the **lowest** gelatin concentration. (1)

28 a C = kidneys; D = lungs (1)

- b 1 mark for correctly placed X's as shown below.



- c E (1)
- d F (1)
- e 1 mark for E and F correctly placed.

Vessel	Diameter / mm	Wall thickness / mm
F	30	1.5
E	25	2.0

- f Aorta (1)
- g Renal veins (1)

29 a Family (1)

- b *Ranunculus* and *Caltha* (1)
- c The genera *Ranunculus* and *Caltha* are smaller groups within the larger family Ranunculaceae (1) and there is no overlap between them. (1)
- d All three species share the observable characteristic of similar flowers so are placed in the same family. (1) Only *R. flammula* and *R. hederaceus* share a lack of seams in their fruits, so they are more closely related to one another than to *C. palustris* (1) and are placed together in the same genus. (1)

30 a Expressed means the gene is being used to synthesise protein. (1)

- b To allow enzymes access for transcription, (1) the DNA in these regions is likely to be less densely packed. (1)
- c Genes are base sequences of DNA (1) that code either for the amino acid sequence of a polypeptide (1) or for the base sequence of a functional RNA. (1)
- d $496 \times 3 = 1488$ bases (1)
- e Their distant ancestors did not eat much starch in their diet (1) so there was little advantage in having more salivary amylase. (1)

31 a Grown in liquid medium (1) and multiplied by cell division/mitosis to increase their number. (1)

- b Activated dendritic cells would be presenting the antigen (1) on their cell-surface membrane. (1)

- c Cytotoxic T cells (1)
- d T cells with cell-surface receptors for the antigen. (1)
- e The middle value of the range of survival times following treatment. (1)
- f Because it is personalised, the treatment is extremely expensive (1). It did increase the **median** time of survival, but only by a few months. (1) It only increased the probability of survival for a further three years by 8.7%. (1) The treatment is therefore not very cost-effective. (1)

Paper 2

Grade booster

- 1 (a) Stopping the expression of genes (1) so that the effect on a cell of not having a particular protein (1) or functional RNA (1) can be detected.
- (b) The mutation is called a duplication. (1) It will result in a series of glutamines (1) being inserted into the amino acid sequence of the polypeptide. This will change the secondary structure (1) and therefore the shape of the protein (1) and prevent it from functioning normally.
- (c) Retaining an intron means that the protein is normal until that point (1) but then the intron codes for incorrect amino acids until an early termination codon (1) occurs, which halts translation (1) at this point.
- (d) Disruption of vesicle transport in neurones would affect synaptic transmission (1) in the brain. (1)
- (e) Small interfering RNA molecules would bind to mutant mRNAs containing the intron (1) and prevent their translation, (1) reducing the amount of harmful clumping protein (1) in neurones.

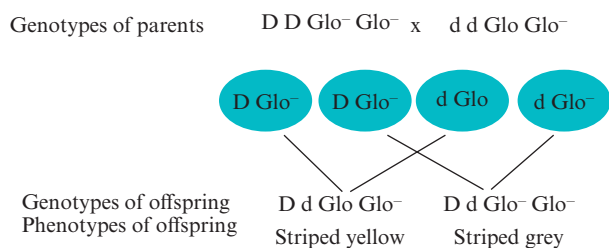
Guided questions

- 2 (a) Sand helps to break up the plant cells and chloroplasts to release the pigments. (1)
- (b) Pencil will not run in the chromatography solvent. (1)
- (c) Add a spot with the pipette, dry (1) and then repeat many times. (1)
- (d) To ensure that they removed the plates from the solvent when the solvent reached the top (1) to prevent any of the pigment bands from running off the plate. (1)
- (e) The black and white **chlorophyll** (1) bands are larger (1) on the TLC plate from the shade plants.
- (f) Less light is available for photosynthesis (1) in the shady site. The plant has made more chlorophyll to absorb more light (1) in the shade.
- 3 Prokaryotic cells contain single circular DNA molecules (1) and often contain some smaller circular DNA molecules called plasmids. (1) Eukaryotic cells contain a number of (1) much larger, (1) linear (1) DNA molecules.
- 4 (a) The base sequence (1) of part of the coding region (1) of a gene.
- (b) So that two barcodes can be created (1) for **all** species of land plants. (1)
- (c) Speciation will have occurred more recently (1) than the formation of families (1) or higher taxa. A faster evolving gene undergoes mutations more frequently (1),

- which makes it more likely that differences in the barcode will have occurred between species. (1)
- (d) It is important that the DNA in the sample remains intact. A lack of water in the material prevents endonucleases (1) from functioning. Amplification increases the number of fragments (1) of the genes for sequencing. (1)
- (e) $\frac{100}{9} \times 35\,000 = 388\,888$ (1) rounded to 389 000 (1)
- (f) Some species will have no differences in their base sequence (1) in the barcoded regions (1) of genes when compared to other species.
- 5 Optical microscopes have a limited resolution (1) that prevents the smallest cell structures or the detailed structure of larger organelles (1) from being observed. Because they use electrons rather than light, transmission electron microscopes are not able to show the colour of material (1) or to observe living material. (1) The preparation of material for use in transmission electron microscopes is more complex and time consuming. (1)
- 6 (a) $0.82 \times 4.39 = 3.60 \text{ dm}^3$ (1)
- (b) Group C, because they have a mean FEV1/FVC ratio of 0.66 (1), which is below 0.7, indicating obstructed airways, and emphysema narrows the airways. (1)
- (c) Less elastic lungs means a lower volume of air can be inhaled each breath. But in a forced exhalation, lung elasticity does not determine the rate of exhalation (1) so the proportion of the inhaled air exhaled in the first second is not reduced. (1)
- (d) Age, sex and body size could all affect the FVC, (1) so these variables have been **controlled** to allow a valid comparison of the effects of the two diseases. (1)
- 7 (a) W = totipotent (1) stem cells, X = pluripotent (1) stem cells.
- (b) Totipotent stem cells are able to form any body cell or placental cell (1) whereas pluripotent stem cells can form any body cell. (1)
- (c) Y and Z = multipotent stem cells. (1)
- (d) Y cells can form several different types of blood cell (1) but Z cells form only muscle fibres. (1)
- (e) Cardiomyocytes are heart muscle fibres. (1)
- (f) Skeletal muscle tissue is able to undergo repair by the division and development of skeletal muscle stem cells (1) but heart tissue cannot regenerate after damage (1) because it does not contain stem cells.
- 8 (a) A (1)
- (b) Pioneer species stabilise the sand/add nutrients/trap windblown seeds of other species. (1)
- (c) Community C has the highest biodiversity. (1) This is because conditions are too exposed and hostile in community A and B (1) for as many species to survive and there is less light for photosynthesis beneath the shrubs and trees (1) in community D and E for as many species to survive.
- (d) Sheep eat young sea buckthorn bushes and prevent them colonising (1) community C and outcompeting smaller species such as pyramidal orchids. (1)
- (e) The pioneer community is frequently washed away (1) by waves, preventing the succession from progressing to the next stage. (1)
- 9 Carrier proteins on the cell-surface membranes (1) of cells lining the ileum have binding sites for a monosaccharide molecule and a sodium ion. (1) When both sites are occupied, both the monosaccharide molecule and the sodium ion are transported across the membrane. Sodium ions are actively transported (1) from the cells into the blood, which maintains the sodium ion concentration gradient (1) and drives the co-transport, drawing monosaccharide molecules into the cells. (1)
- 10 (a) Two neurones (1) because if it is monosynaptic, there is only one synapse. (1)
- (b) 40 ms (1)
- (c) $2 \times 53 = 106 \text{ cm}$ (1) so conduction speed = $\frac{1.06}{0.04} = 26.5 \text{ m s}^{-1}$ (1)
The answer does not take account of the time for synaptic transmission. (1)
- (d) A three-neurone reflex arc involves a sensory neurone from the receptor (1), a relay neurone in the brain / spinal cord (1) and a motor neurone to the effector. (1) The stretch reflex involves only a sensory and a motor neurone. (1)
- (e) The function of reflexes is to allow rapid, often protective, (1) responses that do not require conscious decision making. (1)
- 11 When the ventricles contract, AV valves close and SL valves open, (1) preventing blood flowing back into the atria and allowing it to flow into the blood vessels. (1) When the ventricles relax, SL valves close (1) preventing blood flowing back from the blood vessels into the ventricles. (1) When the atria contract, AV valves open, allowing blood to flow from the atria into the ventricles. (1)
- 12 (a) It is carried in the blood. (1)
- (b) The placenta releases prostaglandins (1) at the end of the pregnancy. (1)
- (c) It is positive feedback (1) because oxytocin stimulates uterine contractions, which increases the pressure on the cervix (1) and stimulates stretch receptors, which results in the release of more (1) oxytocin.
- (d) Following birth, pressure on the cervix stops so the stretch receptors are no longer stimulated. (1)
- (e) **Osmoreceptors** in the hypothalamus (1) detect changes in the water potential (1) of the blood. The hypothalamus then regulates the secretion of ADH (1) by the posterior pituitary gland.

Exam-style questions

- 13 a A mutant variety is a fish in which a new allele has arisen by mutation. (1) A GM variety is one where an allele from another organism has been inserted into the genome of the fish. (1)
- b The wild type fish is DD Glo⁻ Glo⁻ (1) and the mutant GM fish is dd Glo⁻. (1)
- c Grey body having stripes (1) was crossed with yellow body having no stripes. (1)
- d 1 mark for correct genotypes of parents; 1 mark for correct genotypes of offspring and 1 mark for correct phenotypes of offspring as below.



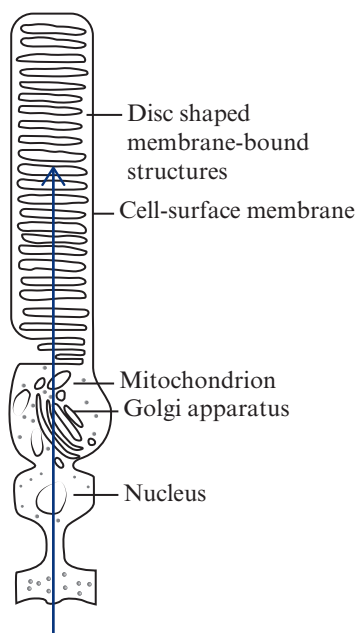
- 14 a** It means allowing time for the apparatus/air inside to warm up to 15°C (1) and allowing the maggots time for their respiration rate to adjust to 15°C. (1)
- b** It prevents the coloured liquid moving if the volume of air inside the maggot tube changes. (1)
- c** A stop clock, because they are measuring a rate, (1) so they need a record of time taken. (1)
- d** Close **both** of the taps to the atmosphere (1) and start the stop clock. (1)
- e** Calculate the volume of oxygen used (1) from the diameter of the capillary tube and the height difference between the two columns of coloured liquid (1) and divide volume by time taken. (1)
- f** Open the two-way tap to the atmosphere (1) and push air into the apparatus using the syringe until the liquid is the same height (1) each side of the U-tube.
- g** They should not keep the maggots in the apparatus for too long without refreshing the air to avoid the maggots using up all the oxygen and becoming stressed. (1)
- 15 a** Flame the mouth of the bottle containing the bacterial culture before transferring some culture to the plate. (1)
- b** To allow the bacteria time to multiply. (1)
- c** A control to check that the paper disc was not responsible in any way for killing the bacteria. (1)
- d** If the bacteria are susceptible to the antibiotic, a clear area is visible where they are killed. (1) Further away from the disc, there is a lower concentration of antibiotic where the bacteria are no longer susceptible. This concentration varies for each antibiotic so the clear zones are different diameters. (1)
- e** Area of T = $142 \times \left(\frac{14.5}{2}\right)^2 = 165.15 \text{ mm}^2$ (1)
Area of S = $142 \times \left(\frac{8}{2}\right)^2 = 50.27 \text{ mm}^2$ (1)
Antibiotic T is $\frac{165.15}{50.27} = 3.3$ times more effective than antibiotic S (1)
- f** Because there is a clear zone around all of the discs so some bacteria are being killed by all of the antibiotics. (1)
- 16 a** T is a trachea and U is a tracheole. (1)
- b** S is a pore that allows gases to diffuse between the atmosphere and the trachea. (1) It can be made smaller or shut to conserve water (1) if the insect is becoming dehydrated.
- c** Oxygen molecules diffuse from the tracheole into the muscle fibre (1) and carbon dioxide molecules diffuse from the muscle fibre into the tracheole. (1)
- d** The muscle fibre uses oxygen for respiration (1) which reduces the oxygen concentration in the muscle fibre so oxygen diffuses down an oxygen concentration gradient between the tracheole and the muscle fibre. (1) This in turn reduces the oxygen concentration in

the tracheole and creates an oxygen concentration gradient between the tracheole and the atmosphere, down which oxygen diffuses. (1)

- e** In insects above a certain size, the distance along the airways between spiracles and muscle fibres would be too large (1) for diffusion to occur fast enough (1) to supply oxygen for respiration.
- 17 a** $3 \times 10^{-3} \text{ s}$ (1)
- b** Because threshold potential has to be reached (1) before an action potential is triggered. (1)
- c** When the threshold potential is reached, sodium ion channels start to open. (1) Sodium ions diffuse into the axon making it more positive, (1) so even more sodium ion channels open. (1)
- d** As the membrane potential becomes more positive, (1) potassium ion channels open and then sodium ions channel close. (1) Potassium ions diffuse out of the axon making it more negative. (1)
- e** 2 ms (1), because hyperpolarisation occurs when the permeability to sodium ions has fallen to zero while the permeability to potassium ions remains above zero. (1)
- 18 a** $\frac{3.8}{100} \times 27000 = 1026 \text{ kJ m}^{-2} \text{ yr}^{-1}$ (1)
- b** $\left(\frac{4.1}{100} \times 27000\right) + \left(\frac{2.3}{100} \times 18000\right) = 1521 \text{ kJ m}^{-2} \text{ yr}^{-1}$ (1)
- c** $\left(\frac{0.7}{100} \times 27000\right) + \left(\frac{4.1}{100} \times 27000\right) = 1296 \text{ kJ m}^{-2} \text{ yr}^{-1}$ (1)
 $1296 + 1026 = 2322 \text{ kJ m}^{-2} \text{ yr}^{-1}$ (1)
- d** Wrens rely on eating the pests so if there is insufficient food, wrens will move elsewhere (1) reducing the biodiversity of the hedge. (1)
- e** Blackfly also feed on spindle trees (1) and the trees remain when the crop is harvested so blackfly can remain in spindle trees (1) from where they can recolonise a new crop.
- f** Removing the pests from the crop greatly increases /more than doubles (1) the yield for humans. However, predators such as wrens that eat pests may go elsewhere and would not be present to control blackfly in spindle trees. (1) Re-infestation of future crops may get worse requiring more/more frequent use of pesticide. (1)
- 19 a** V is coenzyme A; X is reduced NAD. (1)
- b** Mitochondrial matrix (1)
- c** By active transport (1) using carrier proteins. (1)
- d** W contains four carbon atoms; (1) Z contains six carbon atoms. (1)
- e** Six. (1) Glucose contains six carbon atoms, so produces two pyruvate molecules. Each pyruvate molecule produces three carbon dioxide molecules. (1)
- f** Oxygen is required by the electron transfer chain to re-oxidise reduced coenzymes. (1) If the electron transfer chain cannot function, neither can the Krebs cycle, which prevents the link reaction from taking place. (1)
- 20 a** *Agrobacterium tumefaciens* was transformed using plasmids containing bt toxin genes (1) from *Bacillus thuringiensis*. The transformed bacteria were cultured to amplify (1) the required genes. Cotton plants were then infected with the vector bacterium *Agrobacterium tumefaciens*. (1)

- b** The crop can be safely sprayed with the herbicide (1) and only weeds (1) are killed.
- c** Reduced use of herbicides and pesticides (1) has a lower impact on biodiversity. (1)
- d** A mutation occurred in a bollworm giving resistance (1) to the toxin. Most bollworms died but the mutant bollworm survived and the resistance allele was passed on to offspring. (1) The frequency of the mutant allele rapidly increased (1) in the population.
- e** The insect biodiversity is higher in India (1) so other species took advantage of the reduced use of pesticides (1) on the GM crop.
- f** Farmers were trapped into using expensive bt cotton seed (1) because the supply of locally collected non-GM seed ran out. (1) Effective local agricultural practices that kept the cotton crop sustainable were lost as a result of agricultural globalisation. (1)
- 21 a** This was the control, to provide baseline values with which to compare the effects of insulin and adrenaline. (1)
- b** Insulin increases glucose uptake in both sets of muscle fibres, (1) but less so in those from obese rats because they are insulin resistant, so insulin has less effect. (1)
- c** Although the results for adrenaline seem lower, the SD bars overlap, so the difference in glucose uptake between both types of fibres with and without adrenaline is unlikely to be significant. (1) The results support their conclusion. (1)
- d** Adrenaline reduces glucose uptake in insulin-stimulated muscle fibres from both lean and obese rats. (2)
- 22 a** Tick in third box (Crossing over at meiosis is unlikely to separate these alleles.) (1)
- b**
- | | AABB | Aabb | aaBb | aabb |
|--------|-------------|-------------|-------------|-------------|
| Number | 1623 | 59 | 51 | 508 |
| % | 72.4 | 4.7 | 4.1 | 40.9 |
- (1)
- c** The expected ratio of the four different phenotypes would be 9:3:3:1. (1)
- d** The alleles AB and ab are on the same chromosome/linked (1) so the gamete genotypes Ab and aB that can arise only as a result of crossing over are unlikely to occur (1) so the offspring that result from fertilisation by one of these gametes are much less frequent (1) in the offspring.
- 23 a** Muscle cells are able to continue glycolysis by regenerating oxidised NAD, (1) so they are able to produce some ATP. (1)
- b** The amount of ATP they are able to produce per glucose molecule is limited (1) compared to aerobic respiration. (1)
- c** Once sufficient oxygen becomes available, muscle cells can convert the lactate back to pyruvate (1) for active transport into mitochondria. (1)
- d** It produces carbon dioxide, which diffuses out of the root cells so a carbon atom is lost. (1)
- 24** Genetic differences between members of different species can be found by comparing the base sequences of DNA (1) for genes they share. (1) Alternatively, the base sequences of mRNA transcribed from these genes (1) can be compared. Finally, the amino acid sequences of proteins (1) encoded by these genes (1) can be compared.
- 25 a** W is an actin molecule and Z is a myosin molecule. (1)
- b** The actin filament consists of two chains of globular actin molecules (1) wrapped around one another in a double helix. (1)
- c** The myosin filament consists of a number of fibrous myosin molecules arranged in parallel (1) with globular sections called heads extending sideways from the filament in all directions. (1)
- d** X marked on the 'head' attached to the myosin molecule. (1)
- e** Leftwards pointing arrow (1)
- f** Myosin heads bind to binding sites on individual actin molecules forming actinomyosin bridges. (1) The myosin molecules then bend, moving the position of the actinomyosin bridges, (1) which pulls on the actin filament. (1)
- 26 a** Using dice ensures that the quadrats are positioned randomly. (1)
- b** When the running mean becomes constant, the sample can be assumed to be large enough to be representative of the population. (1)
- c** Limpets that overlap the edge of the quadrat on two sides are counted and those on the other two sides are not. (1)
- d** The dice method would not result in quadrats positioned right across the bay (1) so their sample was only representative of the area enclosed by their outermost quadrats. (1)
- e** Calculate the area of their quadrats.
 $50 \times 50 \text{ cm} = 0.25 \text{ m}^2$ (1)
 Find the size of the marked out sampling area in square metres. Divide the sampling area by 0.25. (1)
 Multiply the answer by the **group** mean number of limpets per quadrat. (1)
- 27 a** The root grew downwards and curved, (1) the growth occurred in the central three marked sections. (1)
- b** Cell elongation (1) occurs more on the upper side of the root than on the lower side. (1)
- c** The direction of the force of gravity. (1)
- d** In a horizontal root, IAA transported away from the root tip moves more towards the lower side of the root. (1) IAA inhibits root cell elongation, so the cells on the lower side grow more slowly than those on the upper side, (1) causing the downward curvature. (1)
- e** If all the carrier proteins moved to one side of the cells (1) they could result in IAA transport in a particular direction. (1)
- 28 a** Collect the leaves that fall on one square metre for a certain amount of time / for a year. (1) Dry the leaves to constant mass in an oven. (1) Burn the leaves in a calorimeter to estimate the stored chemical energy. (1)
- b** Mangrove crabs eat leaves containing
 $13\,700 - 3400 = 10\,300 \text{ kJ}$, if they produce faeces containing 9300 kJ, they must absorb food containing
 $10\,300 - 9300 = 1000 \text{ kJ}$.
 If respiration accounts for 96% of that, they must lose
 $\frac{96}{100} \times 1000 = 960 \text{ kJ}$ to the environment. (1)
 $N = I - (F + R)$ so $N = 10\,300 - (9300 + 960) = 40 \text{ kJ}$
 Secondary productivity = $40 \text{ kJ m}^{-2} \text{ year}^{-1}$ (1)

- c Stored in the biomass of decomposers/bacteria (1) or lost to the environment as heat during respiration of decomposers/bacteria. (1)
- d Herbivores and decomposers (1)
- 29 a Upward arrow (1)



- b So there is a greater chance of light being absorbed by rhodopsin molecules. (1)
- c Rod cells respond to very low light intensities but do not distinguish between different wavelengths of light. (1) Different cone cells respond to different wavelengths but do not respond to low light intensities. (1)
- d Rhodopsin breaks down when it absorbs only a very small amount of light. (1) However, light of any wavelength will break down rhodopsin. (1)
- e A change in the electrical potential (1) across the cell-surface membrane of a receptor when it is stimulated. (1)
- 30 a Glycerate-3-phosphate radioactivity increases and then reaches a plateau (1) because it is converted to triose phosphate as quickly as it is formed. (1)
- b Glucose phosphate radioactivity continues to increase during the 3 minutes because some of the triose phosphate is continually used to make it. (1) Sucrose takes longer to accumulate radioactivity because it is made by condensing monosaccharides in additional reactions. (1)

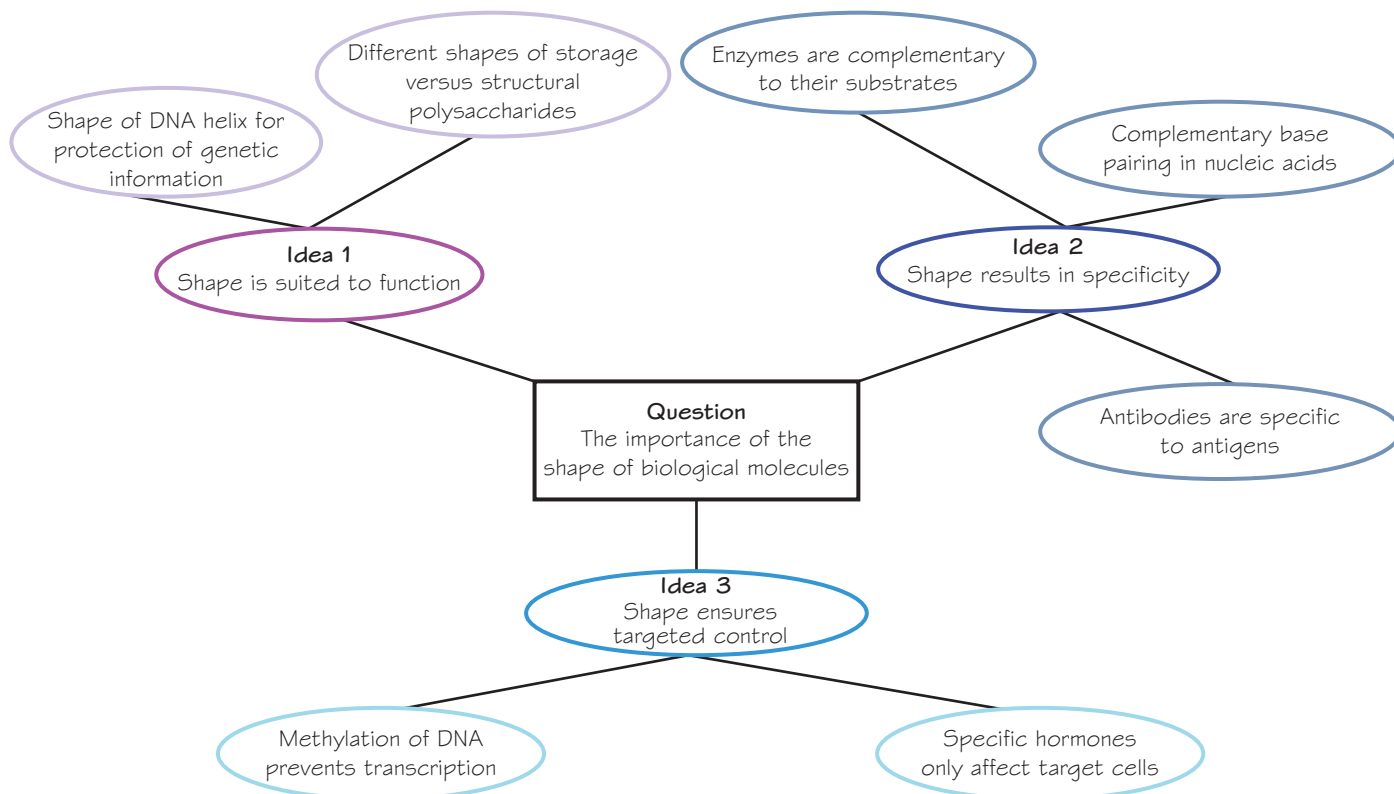
Paper 3

Grade booster

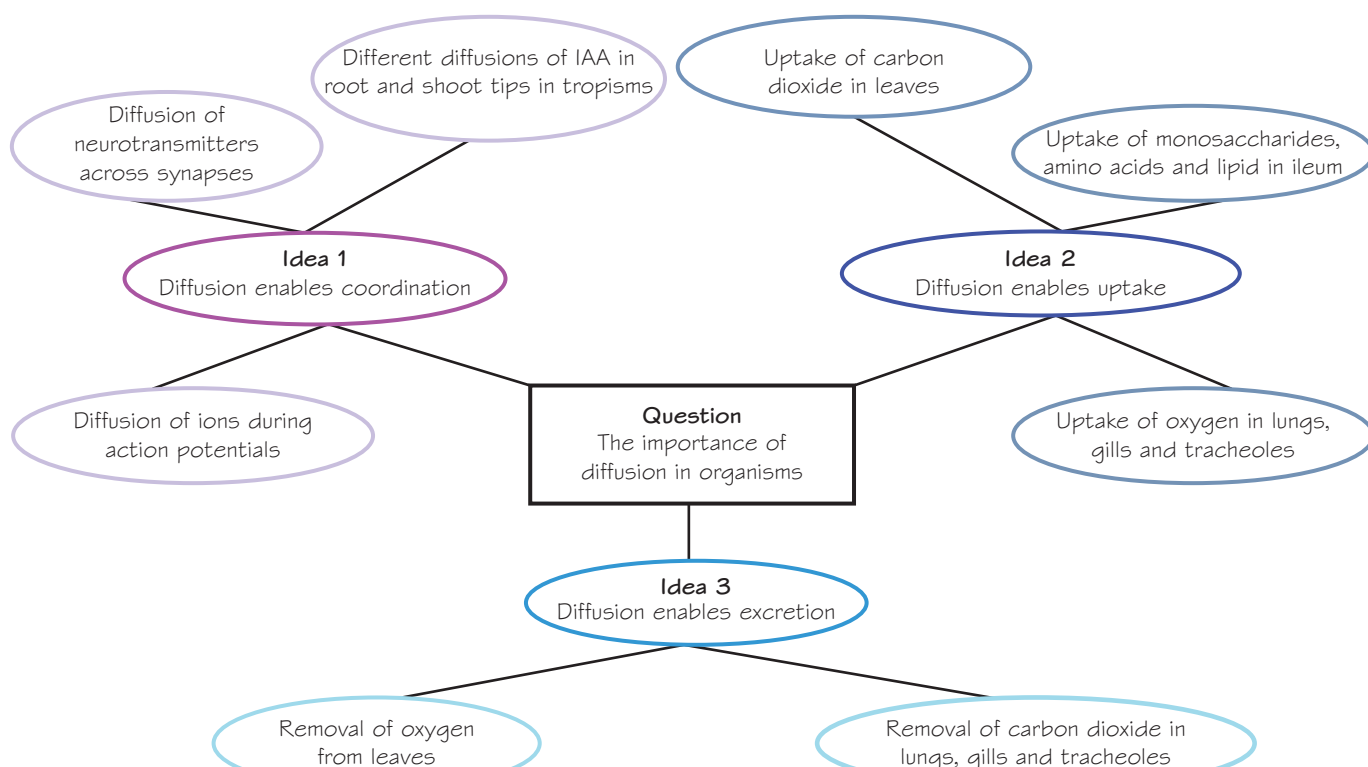
- 1 This essay would score somewhere in the top band (21–25 marks) but is limited to a maximum of 24 marks because evidence of wider reading only relates to one topic. Evidence of wider reading is required for at least two topics.

Guided questions

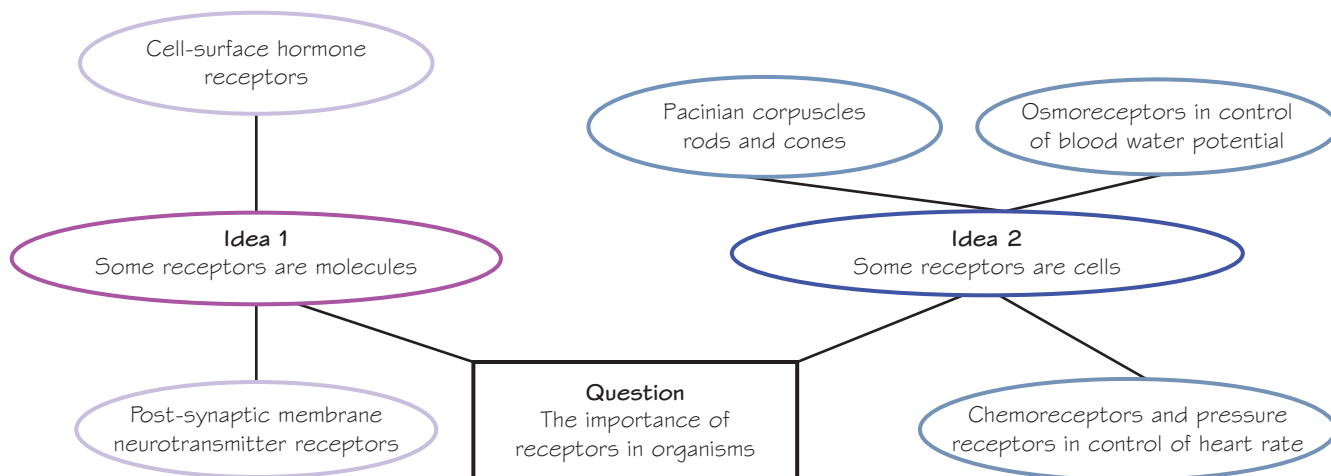
- 2 Essay plan



3 Essay plan



4 Essay plan



5 (a) Area is $40 \times 80 = 3200 \text{ m}^2$

Number of traps is $5 \times 5 = 25$

Number of traps per 100 square metres = $\frac{25}{32} = 0.8$ traps (1)

(b) Increase the number of traps and see if the number of species trapped increased. (1)

(c) They would have counted how many individuals of each species (1) were present in all the traps for one site after four days. (1)

(d) If a lower number of ground insect species was recorded, (1) the index of diversity would be lower than it should be. (1)

(e) There is probably no significant difference between the biodiversity of ground insects in the organic sites and those using fertiliser or between the two non-organic sites because the SD bars overlap. (1) There is a possibly a significant difference between organic

plots and those using fertiliser and pesticide together because the SD bars do not overlap. (1)

(f) In addition to the organic sites and those using both fertiliser and pesticide, there is possibly also a significant difference between the two non-organic sites for ants because these SD bars do not overlap either. (1) However, the difference between organic sites and those using both fertiliser and pesticide is much greater for ants (1) than for all ground insects. The dispersion of the data at both the non-organic sites is smaller for ants than for all ground insects. (1)

(g) Ant biodiversity shows the same response to fertilisers as ground insect biodiversity so would be a good indicator on sites **where fertilisers are being used**. (1) However, ant biodiversity is much more sensitive to pesticides (1) so would not be such a good indicator (1) on sites where pesticides are being used and would not necessarily be a good indicator on sites where other factors (1) might be affecting insect diversity.

- 6 (a) The viral genome is a single RNA molecule coding for ten proteins. (1)
- (b) Because the attachment protein is complementary to the binding sites of receptor proteins (1) **only** found on human airway epithelial cells. (1)
- (c) The capsid is surrounded by a lipid bilayer (1) that will merge with the **lipid bilayer** of the host cell-surface membrane. (1)
- (d) When the host cell fuses with other epithelial cells, (1) virus RNA molecules can pass from one cell to another. (1)
- (e) $44 \times \frac{70.4}{100} = 31$; $44 \times \frac{43.2}{100} = 19$ so $31 + 19 = 50$ men developed an infection. (1)
- (f) The trial showed that RNAi therapy reduced the infection rate by 27.2% compared to the placebo group. (1) However, this was only in healthy adult males deliberately exposed to RSV. The serious effects of RSV are in babies. (1) The trial did not assess how effective it would be for babies, (1) for men already suffering from an infection (1) or for females. (1)
- 7 (a) X is root uptake of nitrate ions and Y is litter formation/death. (1)
- (b) Bacteria (1) living in the soil reduce nitrate ions to nitrogen gas (1), which is lost to the atmosphere.
- (c) **Saprobionts** feed on / decompose organic molecules (1) releasing ammonia, some of which is lost to the atmosphere. (1)
- (d) $82 + 64 + 74 + 8 + 15 = 243 \text{ kg ha}^{-1}$ lost; 197 kg ha^{-1} gained so $243 - 197 = 46 \text{ kg ha}^{-1}$ to maintain the nitrate ion concentration. (1)
- (e) Urine contains organic molecules/urea (1) that saprobionts can use for food, releasing ammonia (1) which is then nitrified (1) so extra nitrate is available for plant growth in urine patches.
- (f) The pasture productivity with inhibitor is higher than with fertiliser. (1) Although more expensive, using less inhibitor could achieve the same productivity as fertiliser. (1) The inhibitor means that nitrate is released more slowly than with fertiliser. (1) It is less likely to be denitrified / leached before plants take it up, so the environmental cost of leaching is reduced. (1)

Exam-style questions

- 8 a It halves the number of stomata on the edge that are counted so it makes the counts more accurate. (1)
- b Area of field of view = $\left(\frac{1.5 \times 10^{-2}}{2}\right)^2 \times \pi = 0.228 \text{ mm}^2$ (1)
There are 8 stomata in the FOV,
so density = $\frac{8}{0.228} = 35 \text{ stomata mm}^{-2}$ (1)
- c To ensure that each field of view was a random sample (1) of stomata.
- d Since the chi-squared value of 6.72 is above the critical value (1) of 5.99 for $p = 0.05$ and 2 degrees of freedom, (1) the stomatal densities of new leaves are significantly different (1) after a period of growth in different carbon dioxide concentrations.
- e It is true that the high carbon dioxide concentration had an effect (1) and the low concentration did not. However, the experiment only investigated

Tradescantia plants, so the results might be different for other species of plant (1). Also, the effect was only on young leaves that grew during the experiment, not on all leaves. (1)

- f In high carbon dioxide concentrations, the carbon dioxide concentration gradient from the atmosphere into the leaf air spaces is steeper (1) so carbon dioxide **diffusion** will be faster (1). This means leaves can supply sufficient carbon dioxide for photosynthesis with fewer stomata, (1) which conserves water.
- g Increasing the number of stomata might possibly result in the loss of too much water (1) for just a small gain in carbon dioxide uptake. (1)
- 9 a To allow a mean value to be calculated, which is more accurate (1) than a single reading.

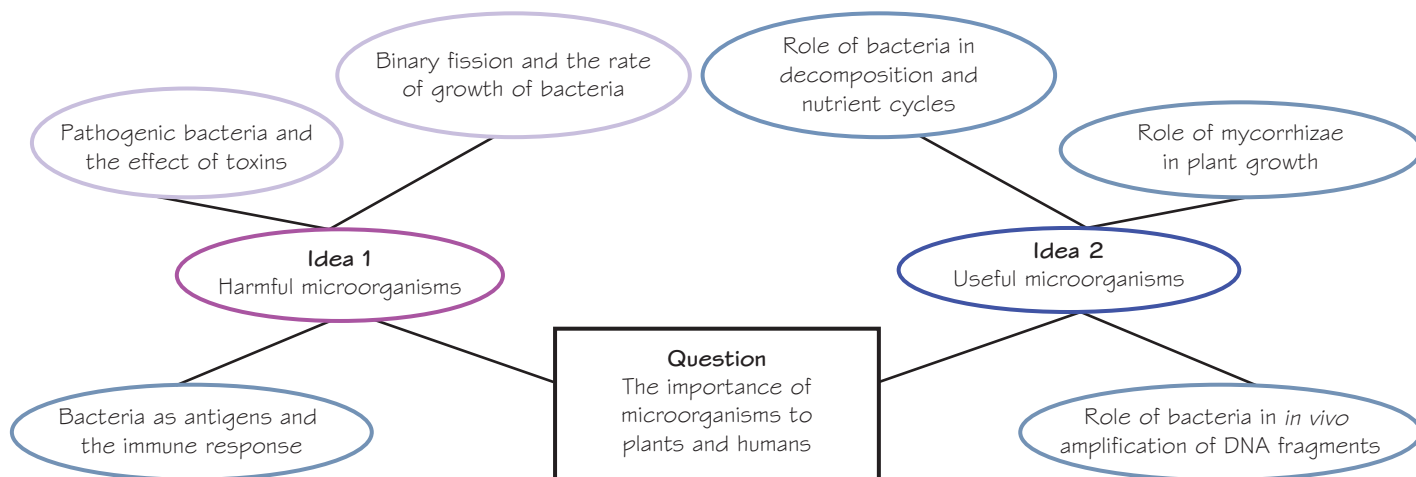
Temperature of water bath / °C	Mean time taken for cross to appear / s	Rate of reaction / $\text{s}^{-1} \times 10^{-3}$
5	90.7	11.0
15	74.6	13.4
35	22.2	45.0
45	125.0	8.0
60	149.1	6.7

Rates shown to the correct number of s.f. including zeros. (1)

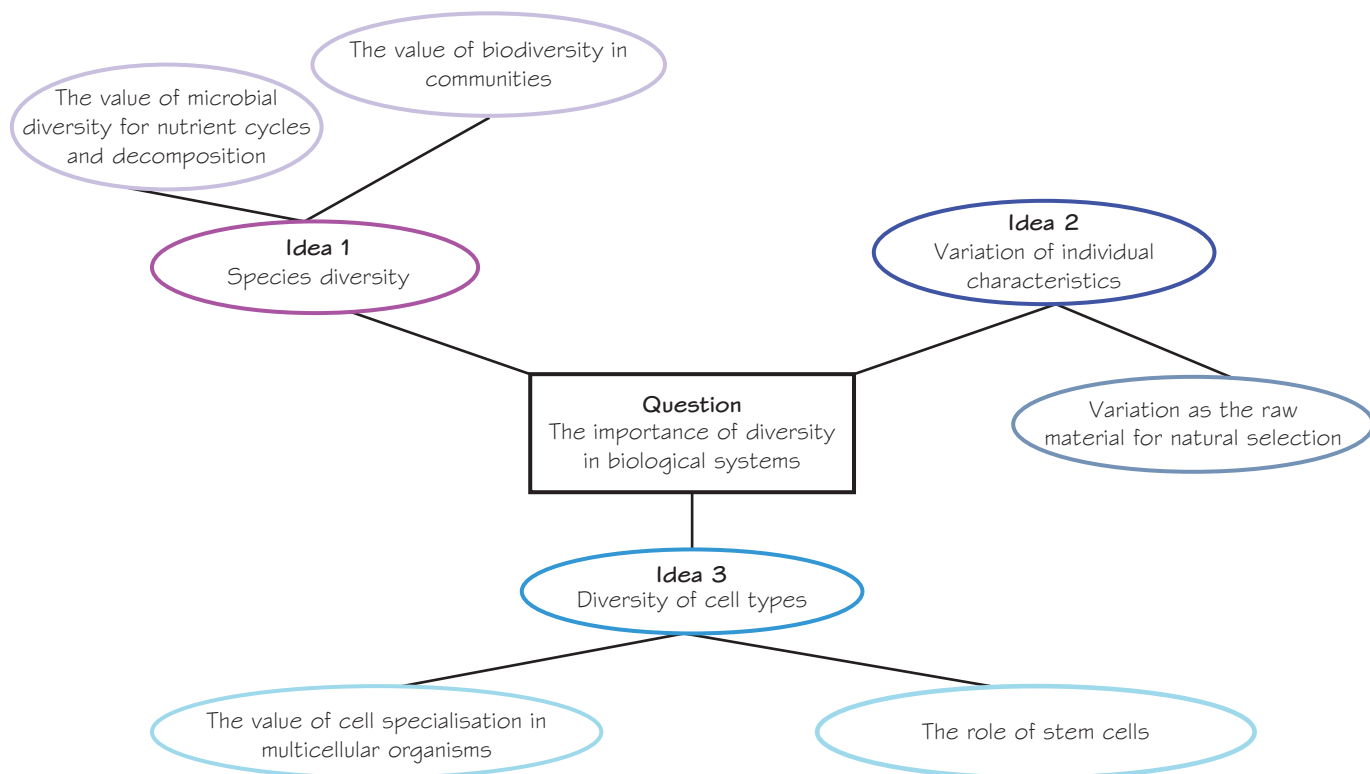
- c Axes linear and labelled correctly (1)
Points plotted correctly (1)
Best-fit smooth curve / points connected with straight lines (1)
- d Judging the disappearance of the cross is subjective and prone to error. (1) However, even given the uncertainty in the method, it is unlikely that 35 °C does not give the highest rate of reaction for these temperatures. (1) However, the chosen temperature intervals mean that it is not possible to conclude with any certainty where the peak of the curve should be positioned. (1)
- e As temperature increases, the molecules in the solution have more kinetic energy so the rate of formation of enzyme-substrate complexes is higher. (1) The tertiary structure of the protease molecules also alters so that the milk protein becomes more complementary to their active sites. (1) However, beyond 35 °C, the tertiary structure of increasing numbers of protease molecules changes irreversibly and the milk proteins are no longer complementary (1) to their active sites.
- 10 a Water is used to calibrate the colorimeter at 100%. (1)
- b A lower percentage of light passes through the algae (1) at wavelengths between 400 and 500 nm and 600 and 700 nm. (1)
- c Algal cells contain chlorophyll. Chlorophyll only absorbs light at certain wavelengths, (1) which results in less light of those wavelengths passing through the algae. (1)
- d Wavelengths in the ranges 400 to 500 nm and 600 to 700 nm (1) would generate the highest oxygen concentrations. (1)

- e When chlorophyll absorbs light, photo-ionisation takes place. (1) This results in electrons being lost from the molecules. (1) Photolysis of water produces electrons to replace those lost from these chlorophyll molecules and it also produces woxygen as a by-product. (1)
- 11 a The table shows whether or not the centrifuge spins fast enough to bring the item down into a pellet. (1)
- b Most organelles are so small (1) that they require a very high spin speed to form a pellet. (1)
- c They overlap in size. (1)
- d The smallest nuclei were too small to spin down in the first pellet. (1)
- e A mixture of small nuclei (1) and large mitochondria (1)
- f When the nuclei were removed, (1) the remaining mitochondria formed a larger proportion of the cell components left in the supernatant. (1)

12 Essay plan



13 Essay plan



14 Essay plan

