BIOLOGY

Paper 9700/11
Multiple Choice

Question Number	Key	Question Number	Key	Question Number	Key	Question Number	Key
1	C	11	A	21	A	31	C
2	B	12	D	22	D	32	A
3	A	13	C	23	B	33	D
4	C	14	B	24	A	34	D
5	A	15	B	25	C	35	D
6	B	16	C	26	A	36	A
7	C	17	D	27	C	37	A
8	A	18	B	28	C	38	D
9	A	19	A	29	C	39	A
10	C	20	B	30	A	40	B

General comments

Ten questions (**2**, **4**, **5**, **7**, **14**, **20**, **24**, **27**, **34** and **38**) were found to be relatively straightforward and eleven questions were relatively more difficult (**3**, **6**, **21**, **26**, **28**, **30**, **31**, **32**, **33**, **35** and **39**). Many of the more challenging questions addressed misconceptions or precise details of plant and human physiology or histology. These questions required the full attention of candidates where they needed to read the question and each option very carefully before making their final choice.

Comments on specific questions

Question 3

Almost all candidates knew that the xylem vessels labelled Q in the photomicrograph have cell walls that contain cellulose and lignin. Some candidates incorrectly thought that they also had plasmodesmata rather than pits, and thus opted for **D** instead of the correct option, **A**.

Question 6

Candidates were asked to identify four labelled biological molecules from a generalised diagram of a virus. A similar number of candidates opted for the correct option **B**, to those who opted for **A** or **D**. Those candidates who chose options **A** and **D** had possibly confused the protein capsid (labelled Y) with the outer envelope (labelled X) that is made of phospholipids.

Question 21

This question asked candidates to consider which processes occur in stem cells during tissue repair. Many candidates knew that DNA replication and cytokinesis would be required in the formation of new cells. Some of these candidates had not realised that the synthesis of proteins would also be necessary and opted for **B**, instead of the correct option **A**.

Question 26

This question required candidates to select the water potential values that could have been measured inside a leaf cell, in the air spaces of the leaf and in the atmosphere. Most candidates understood the direction of the gradient in water potentials and realised that the water potential inside the cells would be the highest, and the water potential in the atmosphere would be the lowest value of the three measures. Although more candidates knew that these water potential values would be negative, a sizable minority thought the values would be positive and opted for **D** rather than **A**.

Question 28

Although there are experimental procedures to apply short duration heat to the stem of a plant to measure sap flow, the method described in this question was for a longer duration. Most candidates realised that 10 minutes at 60 °C would not impact water transport in xylem. Some candidates wrongly assumed that this sustained heat would also not affect the living phloem tissue and opted for **A**, rather than the correct option, **C**.

Question 30

Less than half the cohort selected the correct effect on affinity for oxygen and change in position of the dissociation curve when the mutation lowers the partial pressure of oxygen at which haemoglobin is 50% saturated with oxygen. The most common wrong answer was option **D**, suggesting that these candidates understood the relationship between the variables, but had opted for the reverse trend.

Question 31

A similar number of candidates incorrectly thought that all three of the listed processes were responsible for the Bohr shift (option **A**) compared with those who realised that the first listed processes would have no impact (option **C**). The Bohr shift occurs when there is a decrease in the pH of the blood, but the carbon dioxide that reacts with haemoglobin to form carbaminohaemoglobin will not result in a change in pH.

Question 32

Similar numbers of candidates thought that the blood cell with a large U-shaped nucleus that was found in a sample of blood was a monocyte (option **A**) and a neutrophil (option **B**). The nucleus of a neutrophil is lobe shaped rather than U-shaped. Additionally, neutrophils migrate to the site of infection whereas monocytes circulate in the blood and so these cells are more likely to be found in a drop of blood.

Question 33

Slightly more candidates correctly determined that a molecule of oxygen in the air in the alveolus must pass through a cell surface membrane 5 times to get to a haemoglobin molecule in a red blood cell compared with those who thought it would only pass through 3 times (option **B**). These candidates realised it would need to cross a cell surface membrane to get into the red blood cell; they also needed to consider that the molecule of oxygen would need to pass into and out of the epithelial cell of the alveolus as well as into and out of the endothelial cell of the capillary.

Question 35

Half the cohort correctly identified the tissue that contracts and relaxes to adjust the diameter of the airway in the transmission electron micrograph (option **D**). Many other candidates opted for **B**. Smooth muscle contains elongated cells with tapered ends, rather than the rounder cells visible in the submucosal layer.

Question 39

Many candidates incorrectly thought that the toxoid protein used as a vaccine for tetanus would stimulate the production of antibodies which remain in the blood to provide long-term immunity (option **C**). These candidates had either misread the option or had confused the role of memory cells with those of antibodies. A similar small number of candidates chose option **D**, thinking that the toxin would completely change shape, as chose the correct answer, option **A**. If there was a complete change in shape of the toxoid, the immune response would not be specific to the tetanus antigen. A few candidates deduced that the presentation of the toxoid antigen on the surface of neutrophils would provide immunity against tetanus.

BIOLOGY

Paper 9700/12
Multiple Choice

Question Number	Key	Question Number	Key	Question Number	Key	Question Number	Key
1	B	11	C	21	D	31	B
2	B	12	A	22	D	32	A
3	B	13	A	23	D	33	B
4	B	14	C	24	B	34	C
5	A	15	C	25	C	35	A
6	C	16	B	26	D	36	A
7	A	17	A	27	D	37	B
8	D	18	D	28	A	38	B
9	D	19	A	29	C	39	C
10	A	20	D	30	C	40	B

General comments

In this paper ten questions (**4**, **7**, **14**, **16**, **19**, **22**, **24**, **33**, **28** and **37**) were found to be relatively straightforward and ten questions were relatively more difficult (**1**, **2**, **8**, **12**, **15**, **17**, **21**, **29, 34** and **36**). Questions on gas exchange (**34** and **36**) as well as questions that required the selection of subset of criteria (**8**, **15**, **17**, **36**) were more challenging than those questions that focused solely on an understanding of knowledge. There were also a few questions where candidates may have selected the wrong option by not looking carefully at all of the information such as column headings and diagrams.

Comments on specific questions

Question 1

This question focused on the use of an eyepiece graticule. Many candidates either did not read the second column heading carefully enough, or had a misconception about calibration. The stage micrometer usually has a total length of 1 mm that is subdivided into 100 divisions of 0.01 mm. It is used to calibrate the eyepiece graticule, not the other way around. This means that column 2 was not possible and the only possible use in the table was comparing the diameter of two cells at the same magnification (option **B**).

Question 2

This question required candidates to consider the resolution of a light microscope. Although slightly more candidates selected the correct option (**B**), many other candidates incorrectly chose option **A**. These

candidates may not have considered that the resolution of a light microscope is limited by the diffraction of light or were not able to convert between micrometers and nanometers.

Question 8

Almost all candidates knew that the two proteins, collagen and haemoglobin, would have many double bonds including those at the carboxyl end of each amino acid. About half of these candidates did not know that a saturated triglyceride would also contain three carbon to oxygen double bonds.

Question 12

Although the context of this question was extracellular enzymes, the question was assessing understanding about the location of where enzymes are produced, rather than where they act. Most candidates selected one of the two options (**A** and **C**) that put the production of hydrolytic enzymes used by phagocytes inside cells. About half of these candidates were not mislead by the information that the extracellular digestive enzymes are found in the external environments of some prokaryotes and knew that even if these enzymes are found outside cells, they would still have been produced inside.

Question 15

The unfamiliar context made this question on measuring enzyme activity more challenging. About half the cohort realised that only incubation with the substrate is necessary to determine its activity (option **C**). Some other candidates suggested it was also necessary to incubate the enzyme with its inhibitor (option **B**).

Question 17

Many candidates knew that increases in both the number of cholesterol molecules and the number of unsaturated fatty acids of phospholipids would help to maintain membrane fluidity at low temperatures (option **A**). Some candidates thought that it was only an increase in unsaturated fatty acids that would increase fluidity (option **B**). Other candidates suggested that it was saturated, rather than unsaturated fatty acids, that were required (option **C**).

Question 21

Many candidates saw that the chromosomes in the diagram were positioned near the equator and incorrectly assumed that this would mean that metaphase was being represented. Fewer candidates looked at the centromeres and noticed that the sister chromatids had already separated and correctly realised that it was a diagram of early anaphase. Almost all of these candidates also matched the phase with the correct description and opted for **D**.

Question 29

There was no clear pattern in the options selected to explain the change in diameter of tree trunks at different times over a 24-hour period. Slightly more candidates realised that the tension in the column of the xylem is the main reason why the diameters of tree trunks fluctuate (option **C**).

Question 34

Slightly more than half the cohort knew that most carbon dioxide in the blood is transported as hydrogencarbonate ions (option **C**); a significant minority thought that most carbon dioxide is transported as carbaminohaemoglobin (option **A**).

Question 36

Almost all candidates knew that the blood flow around the alveoli helps to maintain the diffusion gradient for carbon dioxide at the surface of the alveoli. Fewer candidates also realised that the breathing movement exchanging air in the lungs would also be an important factor. Many candidates thought that the thin epithelial lining was a factor. These candidates confused the factors that affect the rate of diffusion with the factors that maintain the diffusion gradient.

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Paper 9700/13
Multiple Choice

Question Number	Key	Question Number	Key	Question Number	Key	Question Number	Key
1	C	11	B	21	A	31	C
2	A	12	A	22	B	32	B
3	C	13	B	23	C	33	C
4	A	14	B	24	D	34	D
5	C	15	D	25	C	35	C
6	B	16	A	26	C	36	C
7	A	17	A	27	D	37	B
8	B	18	D	28	B	38	A
9	C	19	C	29	B	39	D
10	B	20	D	30	C	40	C

General comments

Ten questions (**3**, **9**, **12**, **13**, **14**, **17**, **19**, **21**, **25** and **26**) were found to be relatively straightforward and nine questions were relatively more difficult (**4**, **6**, **8**, **11**, **22**, **27**, **31**, **36** and **39**). Many of the more challenging questions assessed specific details of biological molecules, including polymers (**8** and **11**), chromosomes (**22**) and antibodies (**36**). These questions, and others, highlighted common misconceptions and the need to understand the roles of biological structures (**4**), cells (**39**) and substances (**31**) in sufficient detail.

Comments on specific questions

Question 4

This question asked candidates to consider which cell structures contain ribosomal RNA. A few candidates thought that it was only the nucleus that would have this RNA (option **C**); similar numbers of candidates thought ribosomal RNA would be present in the mitochondria and chloroplasts, or the nucleus and mitochondria (options **B** and **C**). Slightly more candidates realised that as well as the nucleus, both chloroplasts and mitochondria are self-contained in term of protein synthesis, and correctly selected option **A**.

Question 6

This applied question asked candidates to compare the size and mass of bacteria with some eukaryotic cell structures. Slightly more candidates knew that mitochondria and bacteria are similar in size and mass (option **B**) than those who incorrectly suggested that they were more similar to nuclei (option **C**).

Question 8

Fewer candidates selected the correct statement about a macromolecule (option **B**) than selected one of the incorrect statements. The most popular incorrect statement (option **D**) included a reference to triglycerides being polymers even though they are not composed of repeating monomers. The wrong part of the other common incorrect option (**C**) was the mention that haem groups are monomers. To improve, candidates would benefit from a more secure understanding of the terms monomer and polymer.

Question 11

Many candidates knew that products of polysaccharides and proteins contain carboxyl groups (option **C**). There was no clear pattern among the many candidates who chose other combinations of the three listed molecules.

Question 22

This question required candidates to apply their understanding of the terms chromosome, centromere and telomere to diagrams of different stages of the cell cycle. Almost all candidates knew that both ends of each DNA molecule have telomeres and hence excluded options **A** and **D**. Many candidates incorrectly suggested that each of the sister chromatids attached to a centromere are individual chromosomes and opted for **C** instead of **B**.

Question 27

Almost all candidates knew that the photomicrograph through the vascular tissue of a plant was a longitudinal section. Many candidates incorrectly thought is was xylem (option **B**) rather than phloem (option **D**) even though many sieve plates are visible.

Question 31

This question required candidates to select a correct statement about the circulatory system. All four options were selected by similar numbers of candidates, highlighting a number of different misconceptions about blood vessels, blood plasma and tissue fluid. Those candidates who opted for **A** incorrectly thought that the arteries are involved in pumping blood. Option **B** included an incorrect reference to wastes being collected directly into blood plasma and option **D** wrongly suggested that tissue fluid diffuses back into veins.

Question 36

Candidates were required to identify which parts on the diagram of an antibody had been annotated correctly. Almost all candidates knew that the location and description of the hinge region was correct. Many candidates thought that this was the only correct statement (option **D**), or that the description of the variable region was also correct (option **A**). This description was wrong because it referred to the shape being the same, rather than complementary to the antigen. Many candidates did not know that the constant region can bind to receptors of lymphocytes and discounted this statement even though it was correct.

Question 39

The only correct function of plasma cells listed was that they secrete antibodies (option **D**). A number of candidates incorrectly selected that they also differentiate into memory cells (option **B**).

BIOLOGY

Paper 9700/14
Multiple Choice

Question Number	Key	Question Number	Key	Question Number	Key	Question Number	Key
1	C	11	C	21	C	31	B
2	C	12	A	22	D	32	D
3	A	13	A	23	A	33	B
4	A	14	C	24	A	34	D
5	B	15	C	25	D	35	D
6	B	16	B	26	D	36	C
7	A	17	D	27	B	37	A
8	A	18	C	28	B	38	D
9	C	19	C	29	A	39	A
10	D	20	D	30	B	40	B

General comments

Eleven questions (**2**, **5**, **7**, **12**, **14**, **16**, **18**, **21**, **22**, **31** and **33**) were found to be relatively less demanding and ten questions were relatively more demanding (**6**, **8, 9**, **11**, **25**, **29**, **30**, **32**, **35** and **37**). Many of the questions that were more demanding required candidates to read the options very carefully before making their choice. Some candidates could have benefitted by taking greater care to read the information provided. Other questions relied on detailed information associated with collagen (**25** and **32**) and other aspects of biochemistry (**8**, **9** and **11**).

Comments on specific questions

Question 6

This question required candidates to identify which functions are carried out by Golgi bodies. Although almost all candidates knew that they are involved in polypeptide modification and the formation of lysosomes (option **B**), many candidates incorrectly thought that they also carry out exocytosis (option **A**). Although many secretory vesicles produced by Golgi bodies are then released from a cell by exocytosis, this is not a function carried out by Golgi bodies.

Question 8

Slightly more than half the candidates realised that the boiled diastase would have denatured and hence there would be no starch digestion. This would result in a positive iodine test and negative Benedict's test (option **A**). Other candidates may have misread the information in the question and thought that diastase

was active and would break down the starch into maltose, selecting the biochemical test results that would show this (option **D**).

Question 9

Slightly over half the cohort recognised the biochemical reaction as acid hydrolysis of a disaccharide and opted for hydrochloric acid (**C**). Many candidates incorrectly thought this was an enzyme reaction and opted for **A**. Catalase catalyses the decomposition of hydrogen peroxide into water and oxygen.

Question 11

This question asked candidates to select a correct description of globular proteins. Many chose the correct description (**C**); a popular wrong choice was that they always have a quaternary structure of at least three polypeptides (**D**). This is true for haemoglobin as an example of a globular protein, though many enzymes, including amylase, only contain one polypeptide.

Question 25

Stronger candidates recalled that collagen is composed of three polypeptide chains, meaning that there is the possibility that one or more of these chains could code for the different polypeptides, making **D** the correct option. Many incorrectly suggested that only one gene could code for a collagen molecule (option A).

Question 29

Almost all candidates knew that the vascular tissues in plants, xylem and phloem, carry fluids by mass flow. Fewer candidates realised that blood in arteries and veins is also transported in this way. This meant that some candidates opted for **D** instead of the correct option, **A**.

Question 30

Most candidates knew that plasmodesmata are found in both companion cells and phloem sieve tube elements. Many candidates suggested that there were no ribosomes. Phloem sieve tube elements have cytoplasm and cell structures, although these are pushed to the sides. This confusion resulted in many candidates incorrectly opting for **C** rather than **B**.

Question 32

Almost all candidates knew that smooth muscle in arteriole walls is required to adjust the flow of blood to tissues. Some candidates incorrectly thought that collagen was involved in adjusting the resistance to flow as well and opted for **B** instead of **D**. Collagen provides some elasticity to the blood vessels, but is not essential in changing the diameter of arterioles to direct blood flow.

Question 35

This question asked candidates to consider which substance had a direct effect on the affinity of haemoglobin for oxygen. Slightly more than half the cohort realised that the question was testing their understanding of the Bohr effect and correctly opted for the hydrogen ions (option **D**). Others chose carbon dioxide (option **B**), which is what causes the change in pH, rather than the direct effect itself.

Question 37

Slightly more than half the cohort knew that all the factors listed would be economic factors that control the spread of cholera (option **A**). Other candidates chose options that excluded some of the factors. The most common measure to exclude was treating drinking water supplies with high concentrations of chlorine.

BIOLOGY

Paper 9700/21
AS Level Structured Questions

Key messages

Candidates should include units when including numerical values. In **Question 3(b)(i)** and **Questions 6(b)(i)**, **6(b)(ii)** and **6(b)(iii)**, credit was not given if the appropriate unit was omitted.

Candidates are expected to read unfamiliar material, analyse and interpret data, and select the part or parts of the syllabus that are relevant to questions that ask for descriptions and explanations. Some candidates wrote about a particular topic without appreciating that this was not applicable to the context of the question. More time spent analysing the information provided in **Question 5** would have been worthwhile, as many answers missed the most straightforward points.

In **Question 1(b)(i)**, many candidates should have taken more care over their drawings of the two α-glucose molecules. Candidates should use drawings in answers to other questions if it helps them to convey their answers. Many did this in **Question 4(b)(i)**, by drawing metaphase chromosomes with the positions of telomeres indicated by arrows or shading at the end of each chromatid.

General comments

Some questions on this paper proved difficult. **Question 5** involved candidates interpreting information about the movement of phosphate ions within plants and thus relied on information about the structure and function of transport systems in plants from Topic 7, Plant transport, of the syllabus. Many candidates did not use the information and data provided in the question stems. In **Question 5(b)**, candidates wrote about mass flow, loading of sucrose, movement of water into sieve tubes by osmosis and hydrostatic pressures when the question was about movement of phosphate ions. Many misinterpreted the inclusion of the term 'pathway' in the question, and thought they needed to make reference to the apoplast and symplast pathways. Many wrote out the percentages of phosphate in some or all of the regions in group **A** and group **B** without offering any likely explanation for the data.

Candidates should avoid using the word 'efficient' in answers. **Question 3(b)(ii)** was an example. Candidates stated that the enzyme VpSP37 with its low K_m was more efficient than the other enzymes with higher values of K_m. This idea did not gain any credit unless qualified by reference to the fit between substrate and active site.

Although the genetic code was not assessed in this paper, it was clear from some responses that many candidates did not appreciate its meaning. Many used the term when they meant 'nucleotide sequence(s)' or 'base sequence(s)'. This was often the case in **Questions 4(a)(ii)** and **4(a)(iii)**: for example, 'telomeres protect against the loss of genetic code'.

Question 6(b) required candidates to make use of a graph showing the oxygen haemoglobin dissociation curve for three different partial pressures of carbon dioxide. Many candidates did not interpret the dissociation curves correctly. They should know that as oxygen is transported from lungs to respiring tissues, it is helpful to read the graph from right to left. The partial pressure of oxygen in the lungs is to be found on the right-hand side and the partial pressures of oxygen in respiring tissues are on the left-hand side. Lines plotted for line graphs are curves, they should not be referred to as 'graphs', as they were in some answers to **Question 6(b)(iii)**. As with **Question 3(b)(i)**, numerical answers were only accepted if units were included.

Comments on specific questions

Question 1

(a) A concise answer to this question stated that amylose and stearin are large molecules and that amylose is a polymer because it is composed of many repeated monomers. Good answers frequently named the monomer as α-glucose. Often, candidates described the structure of triglycerides to show that stearin is not a polymer. Many candidates needed to pay more careful attention to the question and add that both molecules are large. Macromolecules are not simply made from 'smaller molecules bonded together', as that could apply to compounds such as maltose and sucrose. Some wrote that amylose is not a polymer because it is only made from α-glucose or that it only has glycosidic bonds. These were not credited as this applies to maltose as well as amylose.

(b) (i) There were many excellent answers that completed **Fig. 1.1** correctly by adding water above or adjacent to the arrow and by drawing two molecules of α-glucose. Many candidates omitted the water or showed it as a product of the reaction. Many also did not make accurate drawings of the molecular structure of α-glucose. A common error was to omit the H on carbon atom 5.

(ii) Glycosidic bond was the answer given on many of the scripts. Common errors were hydrogen, covalent, peptide and phosphodiester bonds.

(iii) Hydrolysis was the correct answer to the type of reaction involved in breaking down maltose. The most common errors were 'condensation' and 'hydration'; 'enzyme-catalysed reaction' was also seen quite often.

Question 2

(a) Many candidates stated that cilia have the 9 + 2 arrangement of microtubules but microvilli do not. This was enough to gain full credit. The question revealed many misconceptions; for example, some candidates stated that cilia and microvilli are 'outside the cytoplasm'. There was also the idea that microvilli have microtubules too, whereas the structures that can be seen in **Fig. 2.2** are microfilaments and not microtubules. Many candidates wrote about other features of cilia and microvilli, including their size, appearance, function, density and distribution. A large proportion thought that microvilli contain capillaries and/or mitochondria and many wrote about microvilli as if they were villi.

(b) There was a wide range of answers to this question. The expected answer was the number of microvilli; many candidates gave dimensions of the microvilli such as height, width, circumference and volume. Many gave length, even though this was in the question. Some suggested measuring the distance between microvilli and others explained how to determine the magnification of the image of the microvilli or how to determine the actual size of the microvilli in the image. Some candidates wrote 'amount of microvilli' which was not given credit.

(c) Almost all candidates identified the organelle as a mitochondrion, although many incorrectly used the plural term mitochondria, which was also given credit. Golgi body or Golgi apparatus was stated by a few candidates and some thought that **Z** on **Fig. 2.1** was rough endoplasmic reticulum. Many stated that mitochondria are needed in epithelial cells of the intestine to provide energy or to make ATP. A few went on to gain full credit for stating that the energy is needed for active transport or a form of bulk transport such as endocytosis. Some used knowledge gained about goblet cells to deduce that these are part of the epithelium in the small intestine and stated that energy is needed for making mucus. This answer was given credit. Some candidates stated that the energy released is used for the absorption of products of digestion and needed to add that this is by active transport or active uptake. Candidates should know that substances can also be absorbed across cell surface membranes by simple diffusion or by facilitated diffusion, and that these transport processes do not require ATP.

(d) There were good answers listing the differences between the organisation and distribution of DNA in epithelial cells and bacteria. The main issue for improvement was that many candidates answered only about organisation or only about distribution and needed to include both. Some candidates thought that eukaryotic DNA is a double helix, but prokaryotic DNA is not.

Question 3

(a) (i) Candidates had to describe and explain the similarities between the progress of the two reactions shown in **Fig. 3.2** and **Fig. 3.3**. Using only extracted data was not enough to gain full credit, although the use of data to help support worded explanations, was often helpful. The strongest answers made it clear when a description was being given and when an explanation was being stated.

The expected description was the change in absorbance or the change in the rate of reaction leading to a time when there was no further change in absorbance or when the reaction stopped. Candidates usually gained the credit for this description by stating that absorbance increased in the reaction catalysed by dopa oxidase and decreased in the reaction catalysed by neutrase. Many also described the last part of each curve as a plateau. A point that was often missed was that the change in absorbance was due to the change in colour of the reaction mixtures. Also often missed was an explanation of the changing absorbance in terms of collisions between enzyme and substrate or formation of enzyme-substrate complexes. Many candidates explained the plateaux by stating that the substrate in each reaction was used up. A common error here was to state that the plateau indicated that there was a constant rate of reaction or V_{max} was reached. Another incorrect explanation was that the enzyme active sites were saturated so could not work any faster. The *x*-axis in the two graphs is time, so a constant absorbance means that the reaction has stopped. A common incorrect answer was to state that the rate increased for both reactions.

(ii) There were many good answers to this question, which asked candidates to identify the advantages of using a colorimeter. The question did not ask for a comparison to other methods, but many assumed that this would be by eye, comparing the appearance of the reaction mixtures against a colour chart, or waiting until an end point could be identified. The most common advantages given were that the results are quantitative or numerical and that they are objective. Many candidates explained that judgments made by eye are subjective as no two people necessarily see the same colours. An alternative for the latter point was the idea of accuracy. Smaller numbers of candidates referred to the ability to detect small differences in colour intensity and the ability to use the readings to plot graphs, as in **Fig. 3.2** and **Fig. 3.3**. Very few stated that results could be recorded continuously and stored on a data logger or computer.

(b) (i) Good responses showed how to determine K_m by drawing lines on **Fig. 3.4**. Candidates often wrote out their working to arrive at the correct answer of 0.014 mmol dm^{-3}. Answers between 0.012 mmol dm^{-3} and 0.016 mmol dm^{-3} were accepted. Many candidates missed out on credit as they omitted the unit. A small minority calculated the result in μmol dm^{-3} but often did not multiply correctly, and some left the answer as 40 (½ V_{max}) as they had not drawn a line down to the *x*-axis, while others misread the scale and gave the answer as 0.14 mmol dm^{-3}. Some did not show their working, although credit was given if they had drawn horizontal lines on **Fig. 3.4** to obtain V_{max} and ½ V_{max}. A proportion of the candidates did not attempt an answer to this question.

(ii) Good answers stated that the enzyme VpSP37 has a higher affinity for its substrate so that a lower concentration of substrate is needed to reach V_{max}. Very few gave a correct reason for the high affinity based on the fit between substrate and active site and the ability of the substrate to bind easily. Incorrect explanations often referred to the difference in rates of reaction between enzymes with different values of K_m.

Question 4

(a) (i) A very large number of candidates gave DNA polymerase rather than RNA polymerase as the enzyme that catalyses the transcription of DNA. Other incorrect answers included ‘polymerase’, ‘primase’, ‘helicase’, ‘DNA ligase’ and ‘transcriptase’.

(ii) A number of candidates made suitable suggestions about the functions of the cap and the poly(A) tail. The best answers suggested directing mRNA through nuclear pores to ribosomes and aligning mRNA in preparation for translation. Some suggested that mRNA was protected from damage or breakdown by enzymes; to gain credit it was necessary to state that this was protection from damage by enzymes in the cytoplasm. A small number of candidates stated that these enzymes are ribonucleases. Many confused the roles of these caps and tails with the roles of telomeres. Many candidates incorrectly stated that the cap and poly(A) tail were the start and stop codons

respectively. Some suggested that the poly(A) tail functioned as a flagellum, not making use of the information given in **Fig. 4.1**.

(iii) Answers to this question were of a good standard. Many candidates stated that the process identified as **Y** on **Fig. 4.1** is gene or RNA splicing and described the removal of non-coding introns and the joining of exons. There were some misspellings of exons which were not credited, with 'extrons' being the most common. Incorrect descriptions of introns as 'non-coding genes' were also seen. Many candidates stated that events shown by **Y** involve spliceosomes. A very small number knew that these structures are composed of snRNPs (small nuclear ribonucleoproteins) and are responsible for the cutting and joining of RNA. Many incorrectly suggested that enzymes such as restriction endonucleases and DNA ligase were involved. Some thought that this stage was to do with replication and described the joining of Okazaki fragments. A number of candidates misinterpreted the diagram and described translation of the mRNA.

(b) (i) Telomeres are found at the ends of each chromosome; the ends were often described as tips which was accepted. Many stated that they are at the ends of chromatids which was also accepted. Candidates often wrote that they are found at 'the end' which was not credited. A few candidates included some little diagrams to illustrate their answers and often this helped to secure the credit.

(ii) Some candidates needed to be more precise in their answers, for example stating that genes, genetic information or coding sequences are protected by telomeres rather than 'genetic material'. Telomeres are also genetic material as they are base sequences, and it is some bases in the telomeres that are lost during each round of the cell cycle. Some candidates thought that telomeres are involved in transcription rather than replication. Comparing telomeres with the ends of shoelaces is of limited value because shoelaces do not shorten every time they are used. Many candidates stated that telomeres allow DNA replication to occur many times in the life of a cell and so allow mitosis to occur many times. Stronger responses used correct scientific terminology, for example, writing about DNA replication and/or cell division rather than 'cell replication'.

(c) The answers for this question varied in quality. Most candidates were aware that mutation of a gene that controls the cell cycle can lead to uncontrolled cell division. Many candidates referred to a mutation occurring in the cell, or a cell mutation rather than a gene mutation, or described the mutation as occurring 'in the DNA'. Good answers included the mutation of proto-oncogenes to oncogenes and the absence of a functional tumour suppressor gene. Candidates also mentioned non-functional checkpoints or the failure of cancer cells to undergo apoptosis or respond to signals from other cells. Many candidates noted that uncontrolled cell division leads to the formation of a mass of abnormal cells, though some only mentioned the formation of a mass of cells, which was not credited.

(d) There were many very good responses to this question, in which appropriate terminology was used and the correct context of the identification and destruction of cancerous cells in the body was maintained. Many other candidates needed to pay closer attention to the unfamiliar context introduced in the question stem as they wrote about pathogens and infected cells. To gain credit, candidates had to explain the roles of cytokines and antigens in the immune response. Many attempted this, some writing very well indeed. The best answers made good use of appropriate terminology when describing the action of cytokines and antigens on cells in the immune system often using the terms clonal selection and clonal expansion in the correct contexts. Others wrote what they knew about the roles of T-lymphocytes and B-lymphocytes without linking their answers to the context provided by the question. A few were confused between cytokines and histamine and wrote about cytokines causing inflammation. Weaker responses struggled with precise terminology, often referring to an antigen binding to a lymphocyte with a specific shape rather than binding to a specific receptor on a lymphocyte. A few wrote about antibody binding to an antigen on cancer cells and those who gained credit explained that antibodies mark cancer cells for destruction by macrophages or T-killer cells. Many candidates either wrote about T-killer cells destroying infected cells or cells containing 'the pathogen', whilst others, even though they realised that the T-killer cells were destroying the cancerous cells, did not explain how this is achieved.

Question 5

(a) Success with this question depended on knowledge of the structure of plants and the pathway taken by water and ions from the root cortex to the rest of the plant. The most common explanations were the blockage of the apoplast pathway from root cortex to xylem by the

Casparian strip and the transport of almost all of the water and ions to the leaves in the transpiration stream. The best answers often stated that phosphate ions have to travel through the endodermis (symplast pathway) and so are moved through channel or carrier proteins that might limit the rate at which this transfer from cortex to xylem occurs. Some candidates also stated that phosphate ions may be stored or used in the cells in the cortex so never enter the transpiration stream. Many candidates appeared to have little or no knowledge or understanding of plant anatomy and so gave poor answers or none. Very few candidates noted that xylem tissue does not reach the growing points of plants. Candidates may know this from looking at root tips when studying mitosis and not finding any vascular tissue. Also, water and ions are absorbed by root hairs and travel upwards in the xylem, and not downwards to root tips.

(b) Some candidates were able to apply knowledge of transport tissues in plants to the investigation shown in **Fig. 5.1** and the results in **Table 5.1**. In other responses, simple observations were often missing. It is clear from the results that phosphate ions leave the leaf in phloem tissue and that the ions travel down the stem in the phloem. Some candidates stated that there is bidirectional flow in the phloem but rarely applied that knowledge to state that some of the ions may well have travelled upwards as well as downwards and that explains why the percentages are not close to 100%. Few realised that movement in the xylem is upwards, so the phosphate ions in the xylem tissue in sections **S1** to **S4** must have come from the phloem by lateral movement by diffusion.

The question asked for a discussion, which meant that other possibilities were accepted. For example, some wrote that most of the ions injected into the veins may have been transported out of the leaf to below section **S4** on the stem over the hour of the experiment. The majority of candidates who gained credit for this question wrote about the movement of phosphate ions from phloem to xylem in Group **B** and the effect of the wax paper in blocking this transfer in group **A**. Quite a few candidates thought the wax paper stopped the flow of phosphates through the phloem or xylem rather than between them or thought that the phosphates entered the xylem in the veins rather than the phloem, before trying to travel downwards. Of those candidates who realised that the wax paper was stopping the transfer of phosphates between the phloem and the xylem, there were some who thought the transfer was from the xylem to the phloem, rather than the other way round. Candidates often quoted data from **Table 5.1** without explaining its relevance. The most straightforward comparison to make was between the phosphate content in the xylem in the two groups. Less successful answers gave information about loading sucrose by companion cells and movement of phloem sap in sieve tubes by mass flow or referred to the Casparian strip and/or suberin in blocking movement between of the phosphate ions. Candidates should know that the Casparian strip is found in roots, not in stems. Many candidates wrote only about symplast and apoplast pathways, without further explanation. Many did not show any understanding of the role of the waxed paper, and many did not mention it in their answers.

Question 6

(a) (i) **Fig. 6.1** showed a ribbon model of haemoglobin. Many candidates named part **X** as haem and spelled this term correctly. Prosthetic group and iron/Fe^{2+} were ignored. Common incorrect answers included globin, beta pleated sheet, alpha helix and amino acid.

(ii) Many candidates knew that the function of haem is to bind oxygen or to transport oxygen, and some stated that a molecule of oxygen binds to or is carried by haem. Answers that were not accepted included ‘haem carries four molecules of oxygen’ and ‘an oxygen atom binds to haem’.

(iii) Definitions of quaternary structure were often correct, stating that it involves two or more polypeptides or more than one polypeptide. Some candidates wrote ‘two, or more than two, polypeptides’ which is also a correct way to write this definition. Some confused tertiary and quaternary structure and described the interactions that hold the tertiary structure in shape.

(b) (i) This question asked for the likely partial pressure of oxygen in the alveoli of the mammal. Answers within the range 10 kPa to 14 kPa were accepted. Most candidates gave a single figure although any range within those two partial pressures was accepted. Answers without the unit were not accepted. Some candidates misinterpreted the graph, quoting values for percentage saturation from the vertical axis instead of partial pressures of oxygen from the horizontal axis.

(ii) The accepted range of partial pressures in respiring tissues was between 0 kPa and 6 kPa. A common answer was 0 kPa to 2 kPa. Single figures were not accepted, and no credit was awarded if the unit was not given or was given incorrectly. Candidates struggled with stating the evidence

for this; any answer that referred to the decrease in percentage saturation of haemoglobin with oxygen that occurs over this range was accepted. Candidates often referred to the decrease in affinity of haemoglobin for oxygen and that was accepted as an alternative. Many candidates wrote about the increased saturation of haemoglobin with oxygen rather than the fact that as partial pressure of oxygen decreases in the tissues because of increased rates of respiration, the saturation of haemoglobin with oxygen decreased.

(iii) Many candidates stated that the percentage saturation of haemoglobin decreases as the partial pressure of carbon dioxide in the samples of blood increases. They often explained this effect rather than simply described what is shown on the dissociation curves in **Fig. 6.2** as required by the question. Few stated that the dissociation curve (not the graph) shifts to the right and few described the effect of increasing pCO_2 on the position of the curves on the graph. For example, the largest difference between the curves occurs in the middle of the range shown in **Fig. 6.2**, but at the highest partial pressures of oxygen there is little difference between them. Data quotes, where included, were often correct. Some candidates stated the lowest pO_2 at which 98% saturation was achieved for two or three of the curves and this was credited.

(iv) Almost all candidates knew the effect shown in **Fig. 6.2** is the Bohr effect or the Bohr shift.

(v) Good answers to this question stated that more oxygen is supplied to respiring tissues for aerobic respiration. Weaker answers described oxygen being released from haemoglobin more readily without recognising the importance of the release of additional or more oxygen to meet the high demand for oxygen in cells with high rates of aerobic respiration. Some candidates wrote about the increased demand for oxygen, often linking this to exercise and this was also accepted. Many candidates again used their knowledge of the transport of carbon dioxide in the blood to write about the production of hydrogencarbonate ions and the effect of hydrogen ions on oxygen dissociation. Answers such as this were not accepted.

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AS Level Structured Questions

Key messages

Some questions required candidates to consider the link between two concepts. Here, responses needed to address the links rather than focus only on one aspect. For example, in **Question 1(c)**, good answers highlighted the features of the plant cell wall that allowed an efficient apoplast pathway. Others wrote only about the structural features of the cell wall that prevented lysis or only explained the apoplast pathway. Similarly, in **Question 2(a)**, responses of a high standard described features of haemoglobin that are typical of a globular protein. Others just described a haemoglobin molecule and did not consider the fact that some of the features were not applicable to a typical globular protein.

Candidates should be aware that, although antigens and receptors can be proteins or glycoproteins, they have different roles and the terms cannot be used interchangeably. In **Question 5(a)**, candidates were asked about the specific molecules present on bone marrow stem cells that attach to antibody binding sites. Some incorrectly stated receptor, while others stated antigen/receptor or added receptor in brackets after stating antigen. Answers such as these were not given credit.

Question 6(c)(iii) required an understanding of colorimeters. Candidates should know that these use light of a particular wavelength, which is chosen based on the colour of the solution being tested, and that they provide a quantitative measurement of the absorption, or transmission, of light through a coloured solution.

General comments

Some candidates coped well with the unfamiliar contexts introduced in this examination and were able to draw on knowledge from different parts of the AS syllabus to give high quality answers. Others could have improved by planning extended responses to include the main ideas and most appropriate points, rather than giving a long account which contained some information that was not relevant to the question posed.

Most candidates attempted to answer all items, generally spellings were correct and the appropriate scientific terminology was used in responses.

In **Question 1(b)**, some responses included cell structures or cell types, even though the question only asked for tissues to be named.

In **Question 2(a)**, many needed to be more precise in explaining the location of the amino acids with hydrophilic R-groups on the outside of the molecule or the location of the amino acids with hydrophobic R-groups in the central area. Many missed stating amino acids in their answer or simply wrote about hydrophilic and hydrophobic parts or regions.

In **Question 3(d)**, the distinction between the carrot plant and the carrot was clearly made in the information provided. However, in many answers, it was difficult to discern when the candidates were describing the carrot plant and when the actual carrot was being described, which meant that credit could not always be given.

Candidates should be aware of the importance of legible handwriting so that the difference between letters of the alphabet that are similar is clear. In **Question 4(a)**, *Mycobacterium tuberculosis* gained credit whereas *Mycobacterium tubercolosis* did not. In some answers the letters ‘u’ and ‘o’ were difficult to tell apart.

Candidates should always attempt their answers within the space or answer lines provided. Any continuations or replacements need to be clearly indicated and the additional writing should be associated with a correct reference to the question concerned.

Comments on specific questions

Question 1

(a) Most knew that cell structure **X** was the vacuole of the root hair cell shown in **Fig. 1.1**. However, it was common to see this spelled incorrectly as 'vacoule'. Structure **Y**, the tonoplast, was less well known, with some suggesting that it was the cell membrane. Some candidates did not recognise **Z** as the nucleus in the root hair and gave another cell structure, such as the mitochondrion, for **Z**. As with the vacuole, there were a variety of misspellings given for the nucleus and a number who incorrectly identified **Z** as the nucleolus.

(b) Candidates were able to gain full credit if they stated three correct tissues, in sequence, for this question about the symplast pathway in the root. Others mistakenly described the symplast pathway in one area of the root and named cell structures such as the cell surface membrane and plasmodesmata.

(c) Good answers focused on the structural features of the cell wall for the passage of water in the apoplast pathway. These showed knowledge of how cellulose fibres are arranged to give the spaces needed to make the cell wall permeable to water and the hydrophilic properties of cellulose. Others wrote about the apoplast pathway and included irrelevant detail such as cohesion between water molecules and intercellular spaces. Some wrote about movement of water in xylem vessels.

(d) (i) Most knew the functions of rough endoplasmic reticulum (RER) and smooth endoplasmic reticulum (SER). Well-expressed answers showed an understanding that root hair cells of barley plants and of sorghum require endoplasmic reticulum, but that there would be a higher proportion of RER to SER in the barley plant cells and a lower proportion of RER to SER in the sorghum cells. Weaker answers gave comparative terms between the two plant types by stating, for example, that barley plant cells had 'more RER' than sorghum cells. Some related the presence of the RER and the SER to the secretory function of the cell but did not make the link to their production within the cell. Others thought that RER was involved in phosphate ion synthesis.

(ii) Candidates who took the time to digest the information provided realised that active transport was a transport mechanism that could be discounted for this response. They deduced that root hair cells would not need to secrete the substances if the substances were already present in higher concentrations outside the cells. Many realised that the enzyme would be hydrophilic and the lipid hydrophobic so for student **X** they were only left with the suggestion of exocytosis as a transport mechanism. Here it was straightforward to make the link to the information that Golgi bodies and vesicles were present in the root hairs. Candidates who suggested passive diffusion or facilitated diffusion for both substances were not credited but were given credit for stating the substances would be moving down a concentration gradient. For student **Y**, most suggested diffusion and facilitated diffusion for the different mechanisms of transport, or one of the two plus exocytosis. Candidates who did not get credit for student **Y** often erroneously matched hydrophobic substances with the need to have a transport protein and hydrophilic substances with an ability to cross the phospholipid bilayer or included a need to have active transport. Weak responses wrote about symplastic and apoplastic pathways.

Question 2

(a) The strongest responses considered features of globular proteins that were present in a haemoglobin molecule. This contrasted with responses that just described a haemoglobin molecule with two alpha-globin and two beta-globin chains containing haem groups. These features are not found in a typical globular protein. The most common correct answer was that haemoglobin is soluble. Some missed gaining full credit by writing only about hydrophilic or hydrophobic R-groups or regions, without stating amino acids. Another way of gaining full credit was to express in some way that typical globular proteins have metabolic roles.

(b) Some candidates were able to gain full credit for this question. Candidates who did not state chloride ions, hydrogencarbonate (ions), and hydrogen ions, but who gave Cl^-, HCO_3^- and H^+, were credited. Many candidates did not know about the chloride shift that occurs in respiring tissues or were not able to make the link to the description. A proportion of these incorrectly stated oxygen, which does not enter the cells and can pass through the phospholipid bilayer. Some gave chloride ions and glucose. Glucose was treated as a neutral point. Although it would enter the red blood cell, it does not have a direct role in the transport of respiratory gases. Many knew

carbaminohaemoglobin would be formed when carbon dioxide binds to haemoglobin. There was a range of misspellings for this and not all could be credited. Oxyhaemoglobin was the substance most commonly known by candidates. Carboxyhaemoglobin was the most common incorrect answer.

Question 3

(a) Although many noticed that the positions of the hydroxyl group and hydrogen atom on carbon 1 of galactose should be reversed, fewer noticed that this was also the case for carbon 4. It may have been a good idea to sketch out from memory the ring form of alpha-glucose, as some candidates did, so that it was easier to get a visual reminder of the differences.

(b) The quality of response for this question was extremely varied. Galactose was the only sugar that would not be well known by candidates, but it could be deduced from **Fig. 3.1** that it is a reducing sugar and a monosaccharide. With this information, many gave clear and concise accounts of the evidence in **Table 3.1** that supported the conclusions stated. Common errors were to state that galactose or fructose were non-reducing sugars and/or disaccharides. For conclusion 3, some could have improved their answer by clearly stating that fructose was present in the highest quantity. Instead, they stated that fructose and glucose were in the highest amounts, which was not credited. Others quoted data from the table but did not explain why the data supported the conclusion. The weakest responses stated either 'yes' or 'no' for each conclusion and just repeated the text given by each conclusion.

(c) Most of those who gained credit gave starch or cellulose as their answer. Despite asking for a carbohydrate that was not a sugar, a proportion named sucrose or another sugar from **Table 3.1**, some gave protein and others stated lipid.

(d) Good answers stated that the carrot acts as a source in the second year of growth and as a sink in the first year of growth. It was not precise enough to replace these with statements such as 'after maturing', 'when seeds form' and 'when shoots develop'. Statements such as 'it acts as a sink because it stores sugars when the carrot is photosynthesising' could not be credited as it could not be discerned whether the candidate was writing about photosynthesis in the carrot plant or whether the candidate incorrectly thought that the carrot photosynthesised. Reference to 'nutrients' was too vague to be credited. The weakest responses referred to xylem, water and mineral ions.

(e) This question used an unfamiliar context to assess candidate knowledge of transcription and translation. Most knew that transcription occurred before translation and that DNA was required for transcription, and of these many noted that the potyvirus shown in **Fig. 3.2** only had RNA and related this correctly to an ability to carry out translation. Some omitted to explain that the virus only had RNA. Others did not take in the information that the viral proteins were synthesised in carrot cells. This resulted in some responses trying to explain that the virus did not have a nucleus or the correct enzymes for transcription.

Question 4

(a) *Mycobacterium tuberculosis* was generally well known, although some incorrectly named *Mycobacterium bovis* as the main cause of tuberculosis (TB). The species name had to be spelled correctly. There were fewer errors here than seen previously, with the most common being 'Micobacterium' 'and 'Myobacterium'; tuberclosis' and 'tubercolosis'.

(b) Most knew that *M. tuberculosis* is transmitted as an airborne particle and those who accurately described the organism as being in an airborne droplet gained credit. Some forgot to explain that the airborne droplet contained the pathogen. 'Air droplets' is an incorrect term and should be avoided. To gain further credit, details of how the pathogen was released from the infected person and how it entered the uninfected person were required. Some only gave one half of this transmission. Some responses gave a good account initially but went on to suggest other forms of transmission, such as by touch or by ingestion, and this limited them to partial credit only. Occasionally *M. tuberculosis* had been named in **Question 4(a)**, but the transmission for *M. bovis* was described.

(c) This question asked for the type of therapeutic drug used to treat TB and not the name of an antibiotic. Many knew the correct answer and, if they gave an example, this was treated as a neutral part of the response. However, a proportion only named one or more particular antibiotics

and so did not gain credit. Some candidates confused prevention with cure, so it was fairly common to see 'BCG' or 'BCG vaccine' as an answer.

(d) In **Fig. 4.1**, there were a number of blood vessels that could be seen and many candidates could correctly identify one of them. Some candidates identified the single bronchus by the presence of the cartilage that could be seen in close proximity to the left of the rounded section of the airway. Labelling the same airway as bronchus and bronchiole was considered a contradictory answer and so was not credited for either.

(e) This question required an extended response based on the unfamiliar concept of granuloma formation in lung tissues as a result of infection by *Mycobacterium.* Candidates could see in **Fig. 4.2** that there was an absence of alveoli and other normal lung tissue compared with **Fig. 4.1**, and a large number of white blood cells and infected or dead cells. Different candidates took different approaches and were able to gain credit in a number of ways. There were some good suggestions as to how granuloma formation could affect gas exchange, such as realising that granulomas could lead to a narrowing of the lumen of the airways and affect air flow. It was common to see reference to phagocytosis and macrophages and the potential production of antibodies and cytokines, all of which would contribute to an immune response against the pathogen. Some realised that the granuloma would provide physical barriers to the spread of the pathogen. Weaker responses gave information that was not particularly related to this question, for example, writing about excessive mucus formation, damage to cilia and bursting of alveoli.

Question 5

(a) Most knew that antigens attach to antibody binding sites. Some stated glycoproteins. Others incorrectly stated receptors or receptor proteins or suggested a white blood cell such as lymphocyte or phagocyte.

(b) Many candidates realised that stem cells were capable of mitosis or cell division and stronger candidates knew that those of the bone marrow were able to specialise to form blood cell types, rather than any type of cell in the body. Fewer responses went on to explain that the ability to divide would allow large numbers of red blood cells to be produced or would allow the pool of stem cells to be maintained by self-renewal, or that the cells would be genetically identical. The advantage of using a blood sample rather than bone marrow as the source of stem cells was stated by a few as being non-invasive: it was not appropriate to state that it was easier. Although taking a blood sample is easier than taking bone marrow, the collection of bone marrow stem cells from the few that are in the circulating system is not as easy as taking the stem cells once the sample of bone marrow has been taken.

(c) This question was about artificial blood products, which would also include artificial plasma and vesicles that could act as artificial red blood cells. Many stayed with the concept of the red blood cells of **Question 5(b)** and most creditworthy suggestions were based on an ability to avoid rejection, to avoid passing on disease, to be able to cater for different blood groups and to have a long shelf-life. Most responses were able to gain full or partial credit for this question.

Question 6

(a) Some candidates displayed good knowledge and understanding of enzyme kinetics and how a non-competitive inhibitor affects the rate of an enzyme-catalysed reaction and were able to apply this to horseradish peroxidase (HRP). These candidates took into account the fact that K_m for HRP would remain the same in the presence of the inhibitor. They were able to derive K_m for the curve shown on **Fig. 6.2** as 0.06 mmol dm^{-3}, state this as the answer, and draw a correctly-shaped curve for a non-competitive inhibitor that passed through this substrate concentration value at half the maximum rate of reaction of their curve. Candidates who drew a correctly shaped curve and who could use their curve to derive the correct K_m value were also able to gain full credit. Candidates frequently did not give the units for substrate concentration, and some mistakenly gave answers such as 0.6 mmol dm^{-3} instead of 0.06 mmol dm^{-3}. A number of candidates drew a competitive inhibitor curve on **Fig. 6.2**.

(b) Many gained full credit by stating the correct mRNA nucleotide sequences for the start and stop codons. Others gave a definition of a codon and a correct feature associated with each codon. Some candidates defined a codon but did not accompany this with extra detail and just stated that

the start codon began translation and the stop codon ended the process. This was not sufficient to gain credit.

(c) (i) Most attempted to complete **Fig. 6.4** to show the presence of the detection antibody. Generally, the detection antibody was shown connected in the correct location to a toxin-complexed capture antibody. Some omitted the antibody and only showed the HRP connected, which was not accepted.

(ii) Many were able to give one correct difference between the capture antibody and the detection antibody. A common error was to state that the capture antibody bound the toxin and held it in place while the detection antibody detected the presence of the toxin.

(iii) The standard of response for this question was very varied. Most responses gave a sufficient explanation of how a judgment of colour by eye could result in a negative result being incorrectly diagnosed. Some understood that the colorimeter provided a numerical value associated with the extent of absorption (or transmission) of light through a coloured solution. Some of the weaker responses wrote about the colorimeter detecting different wavelengths of colour. The strongest answers gave clear explanations and showed that they understood the relationship between the concentration of toxin, the quantity of oxidised TMB produced, the intensity of the colour produced, and the colorimeter absorbance reading obtained. Many other responses were confused, with some implying that different colours, rather than different shades (or intensity) of colour would be obtained. Others incorrectly thought that higher absorbance readings were associated with lower concentrations of toxin.

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Key messages

Good answers in **Question 1(b)** described accurately the movement of water or water vapour in terms of water potential. They were able to explain the adaptation of a xerophytic leaf as resulting in a less steep water potential gradient between the leaf and the external atmosphere. This contrasted with weaker responses that used the terms water concentration and water concentration gradient, which should be avoided.

In **Question 5(b)(ii)**, it was important to remember that the non-transcribed strand of DNA is not the template strand for the synthesis of the primary transcript. Some candidates became confused when using the diagram of DNA triplet codes shown in **Fig. 5.3**. This was based on the non-transcribed DNA strand. Candidates should be aware that, apart from the replacement of thymine with uracil, the RNA nucleotide sequence of the primary transcript has the same sequence as the non-transcribed strand of DNA.

Question 6(a) asked candidates to describe the hybridoma method for monoclonal antibody production. A main stage in this method is the fusion of a B-lymphocyte or plasma cell with a myeloma cell. A common misconception when answering this question was to state that a hybridoma cell was created by fusing an antibody with the myeloma cell.

General comments

Candidates who performed well overall on this paper were knowledgeable of the syllabus and paid attention to the command terms used, particularly where a question used two command words or a command word and instructional terms. These candidates also displayed an ability to apply understanding to unfamiliar contexts and to make deductions.

Some candidates who showed knowledge of the subject matter being assessed needed to give some more detail so that they could maximise their chance of gaining full credit.

In **Question 1(b)**, some candidates were unable to describe the difference between evaporation and transpiration. It was a common error for responses to imply that water was lost from the leaf by evaporation, rather than by transpiration.

Question 3(b) highlighted the importance of re-reading a response to check that no careless errors had been made. Some candidates mistakenly stated the wrong species, *S. epidermidis*, when suggesting how proteases could prevent the growth the bacterial population.

Candidates should be reminded to give units when including numerical values in a response. In **Question 4(b)(i)**, some candidates gave the correct value for the Michaelis-Menten constant but did not state the associated unit and in **Question 4(b)(ii)**, units were also sometimes missed out when correct numerical data had been extracted from **Fig. 4.1**.

Comments on specific questions

Question 1

(a) (i) The cell labelled **A** in **Fig. 1.1** was correctly identified as an endodermal cell by some candidates. Others recognised the tissue as the endodermis and stated endodermis cell, which was credited. Epidermal cell, epithelial cell and pericycle were common incorrect answers. Most candidates

identified the tissue in which **B** was located as xylem. The question asked for the cell to be named, and far fewer gave xylem vessel element as the correct answer. The main incorrect answers not based around xylem were phloem, lignin and, if not given for **A**, epidermal cell and epithelial cell.

(ii) The strongest candidates had studied the location of the procambium tissue in **Fig. 1.1** and, using their understanding of the role of stem cells, deduced that new cells for xylem and phloem could be produced if these stem cells divided by mitosis. Some used the term differentiate or specialise to explain the development of the newly formed cells. Others gave more vague answers and showed an understanding that new plant cells could be formed to allow the root to grow or to replace damaged or dead cells. Credit was not given for candidates who wrote generally about stem cells because the question was specifically about the procambium tissue in the roots. Weaker responses suggested that procambium acted as a barrier between xylem and phloem tissue or was another type of transport tissue.

(b) Many candidates were able to state two examples of adaptations that reduce water loss in the leaves of xerophytic plants. A very wide range of mainly structural adaptations was seen, but there were a number who wrote about stomatal closure during the hours of most water loss, which was acceptable. Sunken stomata, trichomes and thick cuticle were commonly seen. All leaves have a waxy cuticle so this in itself would not be considered a xerophytic adaptation. Well-expressed explanations were given by a number of candidates, who gave complete explanations using more relevant scientific terminology. Others needed to improve in this respect, for example water potential gradients should be used instead of water concentration gradients and water vapour, rather than water, should have been described as exiting the leaf through stomata or through the cuticle. Although credit was given for naming hairs, rather than trichomes, the term root hairs or spikes, was seen on occasion, which was not credited.

Question 2

(a) (i) Generally, candidates who did well overall were able to apply their knowledge of the general structure of an amino acid to obtain the correct answer. They realised that only the central carbon atom and hydrogen atom were shown of the general structure and deduced that the R-group of lysine has 4 carbon atoms. Most others gave 3 or 5 carbon atoms as their answer.

(ii) Some candidates deduced that the missing parts of **Fig. 2.1** were the carboxyl and amino groups and added these successfully to gain full credit. Many added NH_2 on one side of the central carbon atom and incorrectly added =O and –OH directly to the other side, leaving out the carbon atom of the carboxyl group. Some were confused with the NH_2 group at the bottom of the structure and thought that only COOH was missing. Some of those who drew out the general structure of an amino acid in the space available were not able to use this to work out what was missing from **Fig. 2.1**.

(b) Many were able to match the correct level of protein structure to the descriptions given of the protein melittin. Poor spellings of quaternary were quite common. Most knew that the sequence of amino acids was the primary level of protein structure. Four melittin polypeptides or alpha helices formed at the end of a polypeptide were frequently erroneously stated to be tertiary structure.

(c) There were many varied and descriptive outlines of how melittin affects the structure of a cell surface membrane. The best responses showed an understanding that the phospholipid bilayer was disrupted by the presence of melittin so that a channel could be formed. Others described the formation of the channel and could have improved by including some description of what was occurring to the phospholipids.

(d) Many candidates were knowledgeable about phagocytosis. Some gave excellent descriptions and were careful to apply their knowledge of the process to cell fragments being taken in and broken down. Weak responses based their answer on pathogens, antigens or whole cells. Some needed to be clearer that lysosomes contain hydrolytic enzymes, and that these can act on the cell fragments within the phagocytic vacuole only after fusion with the lysosome has occurred. It was not necessary to go beyond the breakdown of the cell fragments. Some responses continued and described antigen presentation. A common error was to describe the breakdown of the cells by lysozyme, an enzyme that breaks down bacterial cell walls, or to use the term lysozyme instead of lysosome. There were also some confused answers where candidates wrote about phagocytes breaking down cell fragments to make them available for macrophages.

Question 3

(a) Knowledge of the difference between prokaryotic and eukaryotic cells was assessed. The text before **Table 3.1** supplied the information that bacteria are prokaryotes so that candidates should not have confused what was required in each column. The presence or absence of 80S ribosomes and a cell diameter of 20 μm were better known than circular DNA, with many forgetting that mitochondria and chloroplasts possess circular DNA.

(b) There was quite a variation in the quality of response for this question. Some candidates were able to process the unfamiliar information about the interaction between *Staphylococcus aureus* and *S. epidermidis* and then apply syllabus knowledge to answer the question. A good response began with explaining that the proteases synthesised by *S. epidermidis* would be secreted by the bacteria so that the proteins associated with *S. aureus* could be digested. Some correctly deduced that *S. aureus* would be unable to remain on the skin surface if the polymers associated with the biofilm of *S. aureus* contained proteins that are broken down. Others suggested that there were proteins specific only to *S. aureus* that would be degraded, such as cell surface membrane receptors or transport proteins. Less convincing responses suggested the breakdown of proteins that would be common to each bacterial species, which would mean that the *S. epidermidis* cells would also be harmed.

(c) (i) Most of those who gained full credit knew that goblet cells were responsible for the production of mucus, and that *S. aureus* would be trapped in the mucus. There were some who thought that goblet cells directly took in the bacteria to kill them. Others did not mention mucus and explained the *S. aureus* cells would be trapped and then moved by cilia, which was not credited.

(ii) Ciliated epithelial cell was named by a number of candidates as the other cell type lining the lumen of the trachea. It was not enough to state epithelial cell, ciliated cell or cilia cell.

(d) (i) Candidates were provided with **Fig. 3.2** so that they could assess how vancomycin acted on the cell wall of *S. aureus.* When comparing this to the action of penicillin, similarities and differences needed to be described. Some candidates had no difficulty recalling the mechanism of action of penicillin and could see that both antibiotics prevented crosslink formation so that the synthesis of the cell wall would be prevented. A number of candidates went on to explain that penicillin interacted with the enzyme that formed the crosslinks and then described the more direct effect that vancomycin had on the peptidoglycan components. Some could have taken greater care in their description of the action of vancomycin, stating that vancomycin acted on the peptidoglycan chains, when they should have noticed that the antibiotic was affecting the peptidoglycan components yet to be added to the chain. Weaker candidates wrote about vancomycin or about penicillin as an enzyme. Many incorrectly thought that penicillin broke down the crosslinks or that penicillin caused holes to be formed in the cell wall.

(ii) There were many different approaches to answering this question about reducing the impact of antibiotic resistance. The most common ideas given by candidates were to complete the prescribed course and to take antibiotics only when necessary. Many explained, in various ways, the importance of the effective use of antibiotics for treating diseases. The weaker responses tended to be quite vague or ambiguous. For example, 'take more antibiotics' is less meaningful than describing taking a combination of antibiotics, and 'find stronger antibiotics' was not as clear as the idea of developing new antibiotics. There were some who wrote about antibodies instead of antibiotics.

Question 4

(a) (i) Candidates were knowledgeable about the role of cholesterol in cell membranes. Some found it more difficult to work out how the fluidity of the membrane would be affected by a decrease in the concentration of cholesterol and only a proportion correctly deduced that, compared to the membrane of other organelles, the fluidity would increase. Some wrote about how the fluidity would change with a change in temperature, but this was not relevant to a question about a mammalian cell as the body temperature of mammals remains within a constant range.

(ii) Of those who gained credit in **Question 4(a)(i)**, some correctly related an increase in fluidity to the functioning of lysosomes and the fusion of the membrane with that of a vacuole to allow the release of hydrolytic enzymes.

(b) (i) Many candidates were able to use the data in **Fig. 4.1** and derive a value for K_m as 120 μmol dm^{-3} for α-galactosidase. Some derived the value and needed to include the unit for this substrate concentration for full credit. Extracting the correct value for the maximum rate of reaction, V_{max}, at pH 4.5 was straightforward for most candidates. This value, 2.8 pmol min^{-1}, was then mistakenly used by some as the required value for the Michaelis-Menten constant, K_m. Others knew to take the value and halve it but then gave 1.4 pmol min^{-1} as the K_m instead of using **Fig. 4.1** to read off the substrate concentration at this rate of reaction.

(ii) Some candidates gave complete and concise responses when describing and explaining the differences in the results for the enzyme at pH 4.5 and pH 5.0. Some were more vague, implying that the rate was lower at pH 4.5 (or higher at pH 5.9), and should have emphasised with a clear statement that this was at all substrate concentrations tested. It was more common to see a difference in V_{max} described than a comparison of the different substrate concentrations at which this was reached. Most candidates remembered to include units in their answer when stating values. Many gave one or more suggestions to explain the difference in the result, with a high proportion stating that pH 5.9 must be the optimum, or closer to the optimum, than pH 4.5. Stronger responses gave good ideas about the effect a higher presence of hydrogen ions would have on the activity of the enzyme.

Question 5

(a) There were some responses that remained focused on outlining the role of telomeres in eukaryotic chromosomes. Others gave information that was not relevant to the question, such as describing the location and the nature of the repeated sequence of telomeres or explaining the role of the enzyme telomerase. A common error was to describe telomeres as non-coding genes or genes that do not have important information.

(b) (i) Most gave a correct RNA sequence for the transcribed portion of DNA shown in **Fig. 5.2**. Where credit was not gained, this was for using T instead of U for the complementary nucleotide for A or for making a simple error, for example giving GGC for the last three nucleotides rather than GGG.

(ii) Candidates gaining full credit had deduced correctly to use the complementary nucleotide sequence which would be on the non-transcribed strand, TTAGGG and arrived at leucine and glycine as the two correct amino acids. Many candidates who used **Fig. 5.3** as if the DNA triplet codes were for the transcribed strand, rather than the non-transcribed strand, arrived at asparagine and proline as the two amino acids in the dipeptide.

(iii) The most accurate responses stated that a greater variety of proteins would be synthesised if there is a large increase in the number of genes transcribed in stem cells. Some related this to the ability to differentiate, while others suggested more proteins would be synthesised. These were all credited.

Question 6

(a) Many responses gave a sequential account of the production of monoclonal antibodies by the hybridoma method. Some gave only an outline of the main stages and needed to provide more detail of the method. Good answers described that the immune response produced in the small mammal was to a specific antigen, rather than to a pathogen, and that time was needed for the immune response to occur. These responses also showed an understanding that screening for production of the specific antibody needed to occur so that only the specific hybridoma cells would be used in large-scale culture. A common mistake was to state that antibodies need to be removed from the mammal or that antibodies are fused with a myeloma cell. A number of candidates did not answer the question posed and gave an account of a primary immune response in a person.

(b) A good number of candidates gained full credit for matching a letter to the correct description stated. **S** or **T** from **Fig. 6.1** was accepted as the letter representing the target antigen for abciximab. Some candidates correctly noticed that the platelets were binding together using only antigen **T**. An approximately equal number had thought about the idea of complementary shapes and had noticed that **S** was most likely to be an appropriate shape to fit the antigen binding site of abciximab.

(c) Many knew the sinoatrial node was situated in the wall of an atrium, fewer noted the right atrium. There was some flexibility in the spelling of Purkyne fibres, but greater care needed to be taken to be as close to the correct spelling as possible. Some needed to be more precise for the last gap to be filled, only noting systole rather than ventricular systole as the answer.

BIOLOGY

Paper 9700/24
AS Level Structured Questions

Key messages

The process by which water moves across a cell surface membrane down a water potential gradient should be described as osmosis and not as facilitated diffusion. Water molecules cross the membrane via the phospholipid bilayer and through transport proteins. Candidates should avoid describing movement of water through aquaporins as facilitated diffusion, as some did in **Question 1(b)(i)**. This process describes movement of substances down a concentration gradient, whereas water moves as a result of differences in water potential.

Sometimes it is more accurate to state that partial denaturation of an enzyme has occurred rather than denaturation. **Fig. 2.2** in **Question 2(d)** is a graph showing the effect of temperature on the activity of a lipase enzyme. Above the optimum temperature of 80 °C, there was a decrease in the activity of the enzyme, but at all temperatures recorded the percentage activity was above 50. The strongest responses explained these results as a partial denaturation of the enzyme, or that as the enzyme was beginning to denature above the optimum, and avoided stating that above 80 °C, the enzyme denatured. A denatured enzyme would not be able to catalyse a reaction and so would show zero percentage activity.

Candidates are expected to learn the species names of the organisms that cause tuberculosis (TB), cholera and malaria and also to know the scientific name for HIV, which causes HIV/AIDs. These names need to be spelled correctly. Species names are not the same as type of organism. Although most knew that the type of organism associated with HIV/AIDs is a virus, candidates should also remember that the type of organism causing TB and cholera is a bacterium, and, for **Question 4(a)**, the type of organism causing malaria is a protoctist.

General comments

Generally, candidates showed good knowledge of the syllabus topics on the AS course. Stronger candidates showed an ability to give the appropriate level of detail to match the question posed and made good efforts to introduce the correct scientific terminology when required. Some could have benefited from thinking through how their ideas could be organised to make their response flow better and to avoid giving the same information twice, expressed in different ways. Others gave an idea of the main terms to include in their response and needed to construct more of a statement or sentence for this to be evidence of good understanding and knowledge.

In **Question 1(c)**, given the pressure of time, it was not expected that candidates produce a high-quality diagram showing the distribution of the vascular tissue in the root. There were some who drew labelled diagrams that were easy to credit; many drew diagrams where greater care was needed to show correct knowledge of the exact location of the vascular tissue.

In **Question 2(d)(i)**, some candidates gave very good descriptions of the results shown in **Fig. 2.2** and needed to go on to give an explanation of the results. This limited their ability to gain full credit and is a reminder to candidates to check back to see if they have addressed all of the command and instructional words in the question.

In **Question 3(a)**, asking for a formula assessed candidate knowledge and asking for the actual length assessed the ability to make biological calculations. Some candidates used the box marked ‘formula’ to show their working and did not write out the formula that they used to determine the actual length of the chromosome shown in **Fig. 3.1**.

When describing events occurring in the control and coordination of the cardiac cycle, candidates should avoid using the terms 'signals' or 'messages' because these are not precise enough. In **Question 6(a)(ii)** and **Question 6(b)**, some candidates used these terms instead of giving correct terms such as impulses or waves of excitation.

Comments on specific questions

Question 1

(a) (i) Most knew that chromosomes are arranged at the spindle equator of the cell in the metaphase stage of mitosis. A number incorrectly named anaphase.

(ii) Telophase was correctly named as the stage of mitosis during which vesicles fuse to form new nuclear envelopes. Some candidates named anaphase. Despite being told that the nuclear envelope breaks up into the vesicles early in mitosis, some stated prophase as the answer.

(b) (i) Candidates were asked to outline the process by which water enters the cells in the zone of elongation in the root. Most knew that water molecules move down a water potential gradient and correctly stated osmosis. Some candidates knew that water molecules can pass through aquaporins. Some incorrectly associated movement of water through membrane proteins with the process of facilitated diffusion. Fewer outlined that the water crossed the cell surface membrane and a smaller proportion noted that osmosis is a passive process. Some outlined movement down a concentration gradient, which is not acceptable as a substitute for water potential gradient. Weaker responses suggested that water could also move by active transport. A number misread the question and described movement of water across the root by the symplast and/or the apoplast pathway. It was also fairly common to see answers erroneously based on root hair cells rather than cells in the zone of elongation.

(ii) Most gained some credit with knowledge of the tonoplast, or a description of the tonoplast. A number did not know that the tonoplast is a single membrane and described it as a double membrane. Fewer knew that the vacuole contained cell sap. It was acceptable to give a description of cell sap if the term was not known. Some thought that the vacuole contained cytoplasm. A number outlined the function of the vacuole rather than the structure.

(c) Most candidates drew a transverse section of the root as requested. The diagram drawn needed to show vascular tissue located centrally as one area and not peripherally. This meant that candidates who drew a circle and filled in the entire circle with vascular tissue were not given any credit. Most drew the central xylem as tetrarch (4 arms) and to gain credit the bundles of phloem tissue needed to be shown between the xylem arms, either clearly visible or labelled as such. Quite a few candidates attempted diagrams showing a longitudinal section despite the instruction in the question.

(d) Candidates were told in this question that mass flow occurs after loading of sucrose into phloem sieve tubes. Only some candidates began their response by explaining how mass flow could occur after the loading into the sieve tubes. A relatively high proportion used most of the answer space to describe events occurring in the companion cell before sucrose loading, which was not relevant. Stronger answers detailed movement occurring from the source, which was the root storage, to the growing areas in the stem and gave a sequential account covering all of the main ideas. Most correctly used the term hydrostatic pressure and knew that movement occurred down the pressure gradient. Few candidates explained how unloading at the sink resulted in a lower hydrostatic pressure than at the source. Weaker responses included writing about diffusion, active transport, symplast and apoplast pathways.

Question 2

(a) Most correctly stated extracellular as the answer to this question. The most common incorrect answer was exocytosis.

(b) (i) Only one arrow was required to be drawn on **Fig. 2.1** to show where the bond would be broken between the glycerol and stearic acid residues. Some had no problems clearly indicating the correct bond. Others drew an arrow to or going in the direction of the oxygen of the bond, which was not credited, and some indicated all three bonds between glycerol and the fatty acids, which was not required. Others drew arrows going to various different areas on the palmitic acid and oleic acid residues.

(ii) Most knew the type of reaction, hydrolysis, that occurs to produce stearic acid and that an ester bond is broken. For those who gained partial credit, it was usually for naming the ester bond. There were quite a few that named condensation for the type of reaction, and some that stated esterification.

(c) This question used an unfamiliar context of lipase action on olive oil to assess whether candidates knew that a value of a Michaelis-Menten constant, K_m, represented substrate concentration and whether they understood that the value was derived by using half the maximum rate of reaction (½ V_{max}). Some candidates gave a clear sentence to show a good understanding; others expressed themselves less well and still gave enough evidence in their response to be awarded full credit. Weaker responses gave only part-answers, or wrote about enzyme activity and V_{max} and lipase concentration, or thought that K_m was a value representing half the maximum rate of reaction.

(d) (i) This question about the effect of temperature on the activity of bacterial lipase was answered well by many candidates. There were many who were able to gain full credit by giving accurate descriptions of the results, including correctly extracting data, and then by giving biological explanations of these results. There were a few who demonstrated an understanding that these results showed a wider range of activity than is normally seen, with a higher optimum temperature. Incomplete answers missed out describing results above the optimum temperature, missed out explanations, or gave explanations that lacked the correct scientific terminology. Examples of this were stating energy instead of kinetic energy, collisions instead of enzyme-substrate collisions and denaturation rather than partial denaturation. Some of the weaker responses suggested that above the optimum temperature there was less kinetic energy available.

(ii) Stronger candidates gave differences and detail for this question. Credit was given for suggesting an optimum temperature, or a range, appropriate to digestive enzymes in the human body. Some also realised that the enzyme would be denatured at a temperature not far beyond the optimum. A few used **Fig. 2.2** to visualise that the temperature range for activity of human lipase would be much narrower than that of the bacterial lipase and that the increase to the peak and decrease beyond this would be much steeper. Others simply stated that the optimum temperature would be lower and that the enzyme would be denatured by 120 °C, which was not sufficient to be credited.

Question 3

(a) The formula was usually given correctly by candidates. Although many calculated a correct actual length, those who gained credit also calculated the actual length to the nearest 0.1 μm.

(b) Candidates were knowledgeable about the differences between scanning electron micrographs (SEM) and transmission electron micrographs (TEM). The most common correct feature stated was the 3D appearance of an SEM compared to a 2D TEM image.

(c) Complete answers referred to each chromosome having two sister chromatids joined by a centromere. Some weaker answers referred to sister chromatin, or stated that the chromosomes shown were very similar.

Question 4

(a) Many gained credit for protoctist and spelled this correctly. A large proportion incorrectly gave one of the four species of protoctist, named in the syllabus, that causes malaria, or wrote Plasmodium, despite the genus being stated in the introduction to **Question 4**.

(b) The most popular correct answer was to point out that the red blood cell infected with merozoites shown in **Fig. 4.1** did not have the biconcave disc shape of a healthy red blood cell. A proportion of these also noted the swelling or bulge in the central area of the cell. A large number of candidates wrote about the waste particles present in the image when the introduction to this part of the question explained the presence of these as part of the preparation of the electron micrograph.

(c) Some candidates were able to suggest a use for haemoglobin by *Plasmodium*. Others gave a variety of suggestions which were not feasible, such as suggesting that the red blood cell could no longer carry oxygen so that there was no need for haemoglobin. Some suggested that haemoglobin was broken down in the lifetime of the cell and new haemoglobin was made, but with *Plasmodium* present the haemoglobin was not made; these answers needed to recognise that red blood cells do not have organelles for the production of haemoglobin. Others stated that the haemoglobin concentration decreased because it was bound to carbon dioxide, or to hydrogen ions or that oxygen could not be released. None of these would explain a decrease in the concentration of haemoglobin.

(d) A high proportion of candidates correctly worked out the sequence of steps in the synthesis of MSP1. Of those who gained partial credit, almost all gave step **D** as the first one in the sequence and most knew that step **G** would be the last event before **C**. It was quite common to get steps **A** and **E** the wrong way round.

(e) There were some very well-expressed, complete responses seen for this question, which assessed candidate understanding of secondary and tertiary levels of protein structure. Most candidates were able to gain credit for relating the alpha helix and/or beta-pleated sheet to secondary structure. A common error, which was not credited, was to state ‘beta-plates’. Usually, candidates were able to name two or more correct bonds associated with tertiary structure and a proportion of these responses showed an understanding that these bonds were as a result of interactions between the R-groups of different amino acids in the polypeptide, or gave extra detail about the bonds. Some made correct references to folding and coiling of the polypeptide. Stronger candidates knew details of the hydrogen bonds associated with secondary structure. A few weaker responses showed a misunderstanding of what was required. These candidates answered from the point of view of how secondary and tertiary structure could be disrupted by changes.

(f) The strongest responses included a lot of detail about events in a secondary immune response, because these explain how a person shows active immunity to malaria. Many gave a standard but knowledgeable account of the primary immune response and did not write about the benefits of producing memory cells in response to the antigen in the vaccine. References to T-helper and T-killer cells and antibody production by plasma cells were made as part of describing the primary immune response, when the important aspect was the enhanced production of these cells to combat the pathogen after an actual infection. It was a common error to substitute ‘disease’ for the merozoite antigen or the pathogen when writing about events that would occur in a secondary immune response.

(g) In this question, candidates often listed ways to control *Anopheles* rather than discuss methods. High quality answers related the approaches to control in terms of disrupting the life cycle of the mosquito, which would ultimately reduce vector numbers. There was variation in the use of scientific terminology. For example, few wrote about the mosquito taking a blood meal or sucking blood, with most stating biting or stinging. Some candidates wrote about mosquito babies or children rather than referring to mosquito eggs and larvae. Insecticides or pesticides were described as chemicals that kill or killing drugs. Those who referred to the use of insecticides rarely qualified this with an example, such as using insecticide-treated nets, or spraying wetlands with insecticide. Some ideas were not possible, for example it is not appropriate to cover rivers or spray them with oil. Other responses needed to be less vague and more detailed. For example, many stated a need to reduce water and could have gained credit by explaining that water, for example in puddles or small pools, can be removed to prevent egg-laying or hatching. Others gave a general statement that predators could be used, stronger responses explained that predators could be released into water bodies to eat eggs, larvae or pupae.

Question 5

(a) (i) Some candidates understood that this question assessed their understanding of how cell structure is related to its function and gave good suggestions based on cell thickness and requirements for diffusion as to why ciliated epithelial cells are not suitable as the lining tissue in alveolar walls. Many placed their focus on squamous epithelial cells, which was not what the question asked, and explained why these cells were suitable as the lining tissue. Some thought that ciliated epithelial cells produce mucus and explained how this would hinder gas exchange.

(ii) Candidates knew that cilia of the epithelial cells move mucus and a high proportion qualified this with an explanation of how the mucus would be moved out of the airways. It was too vague to state that the mucus would be moved out of the body and incorrect to suggest that cilia moved it to the stomach. Some candidates did not mention that cilia would move mucus and implied that cilia were responsible for moving pathogens. There were some who correctly explained that without the action of cilia mucus would accumulate, increasing the chance of the trapped pathogens entering the cells of the airways and causing infection. Very few explained the synchronous rhythm that allows cilia to be so efficient in the movement of mucus.

(b) Candidates were not expected to name pollutants when answering this question. It was common for answers to suggest that pollutants decreased the affinity of haemoglobin for oxygen and stronger responses made sensible suggestions about how the pollutants could bind to the haem groups or other parts of the haemoglobin molecule and impair the ability to bind oxygen. This also worked well when candidates named pollutants such as carbon monoxide or sulphur dioxide. There were many who thought of carbon dioxide and made a leap to suggest that this caused a Bohr effect and described all the events that occur to oxyhaemoglobin in respiratory tissues. This was not appropriate for events that occur to haemoglobin arriving at the alveoli that still needs to bind oxygen. In addition, candidates had not taken into account that the diffusion gradient for carbon dioxide in the lungs would still work in the blood-to-alveolus direction. Some did not notice that the question was asking about a healthy person. This meant that descriptions about excessive mucus production or other respiratory conditions were not relevant.

Question 6

(a) (i) Approximately half of the responses named the coronary artery as the main artery serving cardiac muscle. The most common incorrect answer was the aorta, with others naming the pulmonary artery.

(ii) Candidates needed to show an understanding of the role of the sinoatrial node (SAN) and how the SAN was related to ventricular contraction. Some candidates were able to suggest that the slow rate of ventricular contraction was caused by a slower than normal rate of emitting the wave of excitation by the SAN. To gain full credit, candidates could explain some or all of the pathway to the ventricle, either by noting the relationship between the SAN and the atria or by explaining the pathway from the atrioventricular node (AVN) to the ventricles. Some candidates described events occurring in the control of the cardiac cycle and needed to go on to address the concept of the SAN not functioning correctly for further credit. ‘Electronic impulse’ and ‘nerve impulse’ were not acceptable terms to use in this answer.

(b) Many candidates successfully worked through the novel concept of the Wolff–Parkinson–White syndrome to deduce that heart rate would increase and to explain this in terms of the role of the AVN in delaying the impulse in its passage down the septum to the ventricles. A good proportion also realised that the atria and ventricle could be contracting at the same time.

BIOLOGY

Paper 9700/31
Advanced Practical Skills 1

Key messages

Candidates should be given the opportunity to experience a variety of practical work throughout the course, to develop the skills that can be applied to the requirements of the exam.

Candidates should be aware that the wording of a question often indicates how they should respond. The word 'explain' may imply reasoning or some reference to theory depending on the context. For example, **Question 1(a)(iii)** stated: 'Explain how the concentration of hydrochloric acid affects the diffusion distance'. Here, the candidate needed to give reasons why the higher concentrations have a longer diffusion distance than the lower concentrations, rather than just describing the trend in the results.

Candidates should be encouraged to follow instructions carefully when viewing slides under a microscope so that the correct section and tissues are drawn. The fine detail should be included when producing diagrams, for example the tissue layers in plan diagrams and the shapes of cells in high power diagrams. Candidates should be reminded that although cells, such as epidermal cells, have the same common structure, the fine detail of these cells may vary in different plants.

Candidates should be encouraged to read the whole of each question before attempting it so that they can plan their time carefully and answer questions accurately.

General comments

In general, many candidates demonstrated that they had a good understanding of the skills required. There was good discrimination between the weaker and more able candidates and the majority of candidates showed that they were familiar with the use of the microscope.

Candidates demonstrated that they could follow instructions to carry out an investigation skilfully by making suitable concentrations, recording the results in an appropriate table and estimating the concentration of hydrochloric acid in **U**. Candidates should assess their results carefully when estimating an unknown sample and understand that the unknown sample may have a concentration that is different to the standard concentrations.

Candidates showed a high degree of skill when plotting a graph and performing a calculation when measuring a feature on a photomicrograph.

Comments on specific questions

Question 1

(a) (i) The majority of candidates were able to show how to prepare a serial dilution of 2.0 mol dm^{-3} hydrochloric acid, showing the correct concentration below each beaker (0.2, 0.02, 0.002 and 0.002 mol dm^{-3}), transferring 1 cm^3 of the previous concentration to the next beaker and adding 9 cm^3 of distilled water to each beaker. A few candidates showed a serial dilution that reduced the concentration by a factor of a half rather than by a factor of ten.

(ii) The majority of candidates organised their results clearly by presenting a ruled table and included the heading for concentration of hydrochloric acid in mol dm^{-3} and the heading for diffusion distance in mm at 10 minutes and 20 minutes. Candidates gained credit for recording the diffusion distance at 10 minutes and 20 minutes for all the concentrations of hydrochloric acid made and

recorded results which showed that the diffusion distance for the highest concentration of hydrochloric acid was longer than for the lowest concentration of hydrochloric acid. Candidates also gained credit for recording the diffusion distance at 20 minutes the same as or further than that recorded at 10 minutes and to an appropriate degree of accuracy. Many candidates accurately recorded a diffusion distance for **U**. A few candidates only recorded one column of results and some candidates did not include any diffusion distances for **U**.

(iii) A few candidates explained that the higher the concentration of hydrochloric acid the greater the diffusion distance because there was a steeper concentration gradient.

(iv) Many candidates correctly suggested one source of error as the difficulty in judging where to take the measurement of the diffusion distance, as it was not clear where the yellow agar ended and the blue agar began.

(v) Most candidates used their results from 20 minutes in **Question 1(a)(ii)** to correctly estimate the concentration of **U**.

(vi) Most candidates suggested two improvements to the procedure that would give a more accurate value for the concentration of hydrochloric acid in **U**. Many candidates correctly described using concentrations with narrower intervals and the stronger candidates stated concentrations on both sides of their estimate in **Question 1(a)(v)** as examples of the concentrations to use. Many candidates suggested repeating the whole experiment and some gained credit for suggesting the calculation of a mean and a few candidates correctly suggested carrying out the investigation for each concentration of hydrochloric acid separately. The most common incorrect suggestions were to use a colorimeter, a white tile, shorter intervals of time and a different indicator.

(vii) Many candidates calculated the rate of diffusion for 2.0 mol dm^{-3} at 20 minutes by dividing the diffusion distance recorded in **Question 1(a)(ii)** at 20 minutes by 20 or by 1200 seconds. The stronger candidates included the appropriate units in their answer. The most common error was dividing 2.0 mol dm^{-3} by 20 and including mol dm^{-3} in the answer. A few candidates only included time in their answer, and some did not include any units.

(viii) The majority of candidates answered this question in support of the hypothesis. The stronger candidates correctly stated that this was because the diffusion distance was greater in the first 10 minutes than in the second 10 minutes, but many candidates were not awarded credit as they stated the trend produced by the different concentrations of hydrochloric acid. Some candidates did not support the hypothesis and incorrectly stated that this was because the diffusion distance increased after 10 minutes.

(b) (i) The majority of candidates drew the graph, using the headings given in the table to correctly label temperature / °C on the *x*-axis and percentage transmission of light on the *y*-axis. Most of the candidates used scales of 20 °C to 2 cm for the *x*-axis and 20% to 2 cm for the *y*-axis and plotted the points exactly with a dot in a circle or a small cross. Most candidates drew a sharp, clear ruled line through the points.

(ii) The majority of candidates gave a reason for the change in permeability of the cell membrane between 45 °C and 60 °C. Many candidates needed to be more specific about the effect of temperature on the structure of the cell membrane, for example, transport proteins becoming denatured or phospholipids becoming more fluid, and gave a general answer such as the cell membrane being disrupted. Some candidates misinterpreted the graph and also stated that the cell membrane became less permeable so did not gain credit for this question.

Question 2

(a) (i) Credit was awarded to candidates whose drawings did not include any cells and used most of the available space provided. Many of the candidates gained credit for carefully following the instructions and drawing the lamina of the leaf, including the tip, as indicated in **Fig. 2.1**. The stronger candidates gained credit for drawing a line of vascular bundles along the lamina with each vascular bundle surrounded by a ring of cells. The majority of candidates used a label line to correctly label the epidermis. The most common error was to draw the midrib of the leaf with one vascular bundle in the centre not surrounded by a ring of cells.

(ii) Credit was awarded to candidates whose drawings were made using a sharp pencil to produce thin continuous lines which joined up precisely and used most of the space provided. The majority of candidates were able to draw a group of four adjacent cells, two cells from the epidermis and two cells from the layer beneath the epidermis, with each cell touching at least two of the other cells and with double lines representing the cell walls. The stronger candidates showed the correct shape of the cells and the position of the cells beneath the epidermis relative to the epidermal cells. Most candidates used a label line to correctly identify the cell wall of one cell.

(b) (i) The majority of candidates identified at least two observable differences between the section on **J1** and the section in **Fig. 2.2**. Many candidates identified that the section on **J1** was elongated whereas the section in **Fig. 2.2** was circular, that **J1** contained a midrib that was absent in **Fig. 2.2** and that **J1** contained more vascular bundles than the section in **Fig. 2.2**. Some candidates stated that the palisade layer was not well defined on **J1** but was well defined in **Fig. 2.2**. Credit was not awarded when structures that were not observable were included, for example, when the epidermis was referred to as the epithelium or when the section in **Fig. 2.2** was referred to as a cell. A few candidates identified more than three observable features but did not gain further credit for this.

(ii) Many candidates correctly identified one observable feature in **Fig. 2.2** and correctly explained how the feature reduces transpiration enabling the plant to grow in a dry habitat.

(c) The majority of the candidates correctly measured the width of the whole leaf section and the width of the central region in **Fig. 2.2** using the lines **X**–**Y** and **A**–**B** placed across the figure. Most of the candidates recorded appropriate units with their measurements. The stronger candidates showed the division of the measured length of the central region by the measured length of the whole leaf, multiplied the answer by 100 and recorded the correct answer.

BIOLOGY

Paper 9700/32
Advanced Practical Skills 2

Key messages

Candidates should be given the opportunity to experience a variety of practical work throughout the course, to develop the skills that can be applied to the requirements of the examination.

Candidates should be aware that the wording of a question often indicates how they should respond. The word 'explanation' may imply reasoning or some reference to theory depending on the context. For example, **Question 1(a)(v)** stated: 'With reference to the invertase extract, distilled water and sucrose solution, explain the results in **(iv)**'. Here, the candidate needed to refer to their results and make sure that they gave reasons why **W** did not contain reducing sugar and the reason why **E** did contain reducing sugar, rather than just describing the colour produced with Benedict's solution.

Candidates should take care to observe fine detail when viewing slides under a microscope or on a photomicrograph and should include this detail when producing diagrams. For example, in plan diagrams the correct pattern of vascular bundles should be drawn with each vascular bundle containing an enclosed space and, in high power diagrams, the shapes of xylem vessel elements should be drawn. Candidates should also remember that, although cells such as xylem vessel elements have the same common structure, the fine detail of these xylem vessel elements may vary in different plants.

Candidates should be encouraged to read the whole of each question before attempting it so that they can plan their time carefully and answer questions accurately.

General comments

In general, many candidates demonstrated that they had a good understanding of the skills required. There was good discrimination between the weaker and more able candidates and the majority of candidates showed that they were familiar with the use of the microscope.

Candidates demonstrated that they could follow instructions to carry out an investigation skilfully and record the results in an appropriate table. Candidates also showed that they could estimate the concentration of reducing sugar in **W** and **E** according to their results.

Candidates showed a high degree of skill when plotting a graph and performing a calculation when measuring a feature on a photomicrograph.

Comments on specific questions

Question 1

(a) (i) Most candidates completed **Table 1.2** with the correct volumes of **R** to make 0.1 and 0.05 percentage concentration of reducing sugar and the correct volumes of **W** to make 20 cm^3 of each concentration of reducing sugar stated in **Table 1.2**.

(ii) The majority of candidates organised their results clearly by presenting a ruled table and included the heading for percentage concentration of reducing sugar and the heading for time in seconds. Candidates gained credit for recording a time for all the concentrations of reducing sugar stated in **Table 1.2** and recorded results which showed that the time taken to the first appearance of a colour change for the highest concentration of reducing sugar was shorter than the time taken for the lowest concentration of reducing sugar. The majority of candidates gained credit for recording time

in whole seconds. A few candidates did not include the time for 0% in their table so did not gain credit for recording a result for each concentration of reducing sugar.

(iii) Many candidates recorded the time for **W** as more than 120 and a time for **E** that was shorter than the time for **W**.

(iv) Most candidates used their results from **Question 1(a)(ii)** and **Question 1(a)(iii)** to correctly estimate the concentration of reducing sugar in **W** and **E**.

(v) Many candidates explained that **W** contained sucrose solution and distilled water so the sucrose solution was not broken down and the stronger candidates also explained that the invertase extract was added to the sucrose solution in **E** instead of distilled water, which broke down the sucrose solution to reducing sugars. Some candidates explained that the Benedict's solution did not change colour in **W** because sucrose is a non-reducing sugar. The most common incorrect answers suggested that **W** did not change colour with Benedict's solution because the distilled water had diluted the sucrose solution and that invertase contained reducing sugar which caused the colour change with Benedict's solution.

(vi) Most candidates suggested two improvements to the procedure that would give a more accurate value for the estimated concentration of reducing sugar in **E**. Most candidates correctly described using concentrations with narrower intervals and the stronger candidates stated concentrations on both sides of their estimate in **Question 1(a)(iv)** as examples of the concentrations to use. Many candidates suggested repeating the whole experiment and calculating a mean. The most common incorrect answer was to use a thermostatically controlled water-bath.

(b) (i) The majority of candidates drew the graph, using the headings given in the table to correctly label percentage concentration of catalase on the *x*-axis and number of bubbles of oxygen in 5 minutes on the *y*-axis. Most of the candidates used scales of 2% to 2 cm for the *x*-axis and 20 bubbles to 2 cm for the *y*-axis and plotted the points exactly with a dot in a circle or a small cross. Many candidates drew a sharp, clear ruled line or a curve accurately connecting the points. The most common errors were to use a non-linear scale on the *y*-axis so that the points could not be accurately plotted, not plotting the point at 0% or not drawing the line down to the point at 0%.

(ii) The majority of candidates gained credit for correctly stating the percentage concentration of catalase that gave an anomalous result as 6%.

(iii) Most candidates correctly described the trend shown by the results in the graph.

(iv) A few candidates gained credit for suggesting that the breakdown of hydrogen peroxide still takes place slowly without the presence of catalase. Some candidates did not use the information in the graph and incorrectly stated that as catalase was not present hydrogen peroxide did not break down, so no bubbles of oxygen were produced.

(v) The majority of candidates suggested measuring the volume of oxygen as a more accurate method of measuring the oxygen produced.

Question 2

(a) (i) Credit was awarded to candidates whose drawings did not include any cells and used most of the available space provided. The majority of candidates gained credit for carefully following the instructions and drawing the region of the stem on **K1**, as indicated in **Fig. 2.1**. Stronger responses were credited for drawing the correct pattern of vascular bundles and each vascular bundle containing an enclosed space. The majority of candidates used a label line to correctly label a vascular bundle.

(ii) Credit was awarded to candidates whose drawings were made using a sharp pencil to produce thin continuous lines which joined up precisely and used most of the space provided. The majority of candidates were able to draw a group of four adjacent xylem vessel elements, one large xylem vessel element and three small xylem vessel elements with double lines representing the walls of the xylem vessel elements. The stronger candidates showed the correct shape of the xylem vessel elements. Most candidates used a label line to correctly identify the cell wall of one cell. The most common error was to draw one large circular xylem vessel element and three small circular or square xylem vessel elements.

(b) (i) The majority of candidates correctly measured the width of the vascular bundle in **Fig. 2.2** using the line **P**–**Q** placed across the figure and most recorded appropriate units with their measurements. The majority of responses showed the division of the measured length of the vascular bundle by the magnification and recorded the correct answer in micrometres.

(ii) Some candidates successfully identified one observable similarity and two observable differences between the vascular bundle on **K1** and the vascular bundle in **Fig. 2.2**. Most candidates, however, answered in terms of the whole section on **K1** and the whole section in **Fig. 2.2** rather than with reference to the vascular bundles only . Some candidates gained credit for stating that the section on **K1** and the section in **Fig. 2.2** both contained xylem and phloem, or that the xylem was larger than the phloem or that the xylem had thicker walls than the phloem. Many candidates were awarded credit for observing a difference in the arrangement of the xylem vessels, in **K1** they were circular and in **Fig. 2.2** they were arranged in a cross shape. Credit was also given to candidates who observed that the vascular bundle in **K1** was oval but the vascular bundle in **Fig. 2.2** was circular and that the ring of cells surrounding the vascular bundle in **Fig. 2.2** was absent in **K1**. A few candidates identified more than three observable features, which was not required.

(iii) Some candidates correctly stated iodine as a suitable reagent for identifying the storage polysaccharide labelled **X** on **Fig. 2.2**.

BIOLOGY

Paper 9700/33
Advanced Practical Skills 1

Key messages

Candidates should be given the opportunity to experience a variety of practical work throughout the course to develop the skills that can be applied to the requirements of the exam.

Candidates could be asked to suggest how to extend an investigation to answer a new question, for example by investigating a different independent variable. In this case, candidates were required to suggest how to modify the procedure to investigate the effect of temperature on the movement of water between the sodium chloride solution and the cells in the plant tissue. Candidates needed to show that the length of the potato tissue was to be standardised and only one length used while the new independent variable, temperature, was to be changed. Candidates also needed to show that at least five different temperatures were to be used to investigate the effect of temperature on the movement of water.

Candidates should be encouraged to read the whole of each question before attempting it so that they can plan their time carefully and answer questions accurately.

General comments

Candidates who have used materials and apparatus during practical work as part of the course are likely to perform better in the exam. Whilst the activities in the exam may not be familiar, candidates who have had the opportunity to follow instructions carefully in a variety of practical work are likely to find it easier to organise and complete unfamiliar activities.

In general, many candidates demonstrated that they had a good understanding of the skills required. There was good discrimination between the weaker and more able candidates and the majority of candidates showed that they were familiar with the use of the microscope.

Comments on specific questions

Question 1

(a) (i) The majority of candidates stated the diameter of one cylinder of plant tissue and calculated the radius correctly and used the appropriate units, mm or cm.

(ii) Most candidates stated the volume of **S** that was put into each beaker and gave a reason for the volume used, such as to completely submerge the plant tissue.

(iii) Many candidates completed **Table 1.3** by correctly calculating the surface area of one piece of plant tissue and the total surface area of the whole piece of plant tissue for n = 1 and h = 40 as well as n = 16 and h = 2.5. The most common error was using the radius measured in cm rather than mm.

(iv) The majority of candidates correctly stated that the total surface area increased when one whole cylinder was cut into 16 smaller pieces.

(v) The majority of candidates organised their results clearly by presenting a fully ruled table. The stronger candidates included an appropriately detailed heading for the independent variable (number of pieces) and the dependent variable (length with appropriate units, mm or cm). The most common errors were stating that the heading for the independent variable was ‘beaker’ or to

include 'mm' in the body of the table. The majority of candidates gained credit for recording the lengths as whole millimetres or whole centimetres or to the nearest 0.5 cm. The stronger candidates recorded the correct trend, showing that the higher the number of pieces the shorter the total length.

(vi) Many candidates described the correct trend, according to their results, with reference to the total surface area and the total length of the cylinders.

(vii) A few candidates correctly explained the trend in their results by referring to the increased surface area in contact with the sodium chloride solution and the shorter distance for diffusion to take place from the solution to the centre of the potato cylinders.

(viii) Many candidates correctly stated a source of error in the investigation when measuring the dependent variable by describing the difficulty of lining up the cylinders and trying to avoid gaps between the potato pieces when measuring the total lengths.

(ix) Some candidates correctly suggested that using one length of plant tissue and at least five different temperatures would be suitable modifications to the procedure so that the effect of temperature on the movement of water between the solution and the cells in the plant tissue could be investigated.

(b) (i) The majority of candidates drew the graph using the headings given in the table, with percentage concentration of sodium chloride on the *x*-axis and percentage number of whole red blood cells on the *y*-axis. The stronger candidates used scales of 0.2 to 2 cm for the *x*-axis and 20 to 2 cm for the *y*-axis, plotted the points exactly with a small cross or dot in a circle and drew a sharp, ruled line accurately connecting each of the points. The most common errors were not including a full label for each axis, not labelling the scale every 2 cm, plotting points which were not circled, and drawing lines which did not go through the plotted points exactly.

(ii) Many candidates correctly stated that 0.9% sodium chloride solution had the same water potential as the red blood cells.

(iii) Many candidates correctly explained that the effect of 0.4% sodium chloride solution on red blood cells was that water entered the red blood cells as the water potential of the sodium chloride solution was high and the water potential of the cells was low.

Question 2

(a) (i) The stronger candidates produced drawings using a sharp pencil to draw clear, sharp lines which joined up precisely, did not include any shading and used most of the space provided. Many were able to draw the epidermis as a double line with at least two layers of tissue within the stem. Many candidates drew at least two vascular bundles which were subdivided into at least three areas. The most common error was not showing all the different tissues and their correct distribution, which would be observable using the microscope. Most candidates used a label line and label to correctly identify the phloem in the top half of the vascular bundle.

(ii) Credit was awarded to candidates whose drawings were made using a sharp pencil which joined up precisely, did not include any shading and used most of the space provided. The majority of candidates gained credit for drawing a line of four xylem vessel elements, each touching at least one other vessel element and at least two vessel elements with more than four sides. Most candidates used a label line and label to identify the lumen.

(b) (i) Many candidates correctly calculated the actual length of one eyepiece graticule unit by dividing 0.1 mm by 40 and showing the answer as 2.5 μm.

(ii) Many candidates correctly stated that the section of vascular tissue **T** was equivalent to 26 eyepiece graticule units and then multiplied this number by their answer to **Question 2(b)(i)**. The stronger candidates included the appropriate units with their actual length of the vascular tissue **T**.

(c) (i) Many candidates listed three correct observable differences between the stem on **L1** and the stem in **Fig. 2.3**, such as the position of the vascular bundles on **L1** being located in a ring close to the epidermis and the vascular bundles being scattered in **Fig. 2.3** or all the vascular bundles on **L1**

being a similar size while those in **Fig. 2.3** were either large or small and the xylem vessels arranged in a line on **L1** while the xylem vessels were scattered in **Fig. 2.3**.

(ii) Many candidates correctly identified the plant organ on **L1** and in **Fig. 2.3** as a stem and stated the observable feature that helped to identify the plant organ, such as stems have dispersed vascular bundles (in roots, the vascular bundles reside within the central core). Other answers were also acceptable and were credited.

BIOLOGY

Paper 9700/34
Advanced Practical Skills 2

Key messages

Candidates should be given the opportunity to experience a variety of practical work throughout the course to develop the skills that can be applied to the requirements of the exam.

Candidates should learn the methods for testing biological molecules as specified in the syllabus, such as the Benedict's test. The volume of Benedict's solution must be the same or more than the volume of the sample being tested and the temperature of the water bath should be at least 80 °C and up to 100 °C. In this case, the candidates were required to determine the concentration of reducing sugars in a solution. Candidates needed to show that at least five known concentrations of reducing sugars were to be prepared and then tested with Benedict's solution, recording the time to the first colour change for each concentration. The solution with the unknown concentration of reducing sugar would also be tested with Benedict's solution and the time to first colour change compared to the results for the known concentrations to estimate the concentration of reducing sugars in the solution.

Candidates should be encouraged to read the whole of each question before attempting it so that they can plan their time carefully and answer questions accurately.

General comments

Candidates who have used materials and apparatus during practical work as part of the course are likely to perform better in the exam. Whilst the activities in the exam may not be familiar, candidates who have had the opportunity to follow instructions carefully in a variety of practical work are likely to find it easier to organise and complete unfamiliar activities.

In general, many candidates demonstrated that they had a good understanding of the skills required. There was good discrimination between the weaker and more able candidates and the majority of candidates showed that they were familiar with the use of the microscope.

Comments on specific questions

Question 1

(a) (i) Most candidates were able to show how to prepare a serial dilution, showing the correct concentration below each beaker, 0.50%, 0.25%, 0.125% and 0.0625%, and transferring 10 cm^3 of the previous concentration to the next beaker and adding 10 cm^3 of distilled water to each beaker.

(ii) The majority of candidates organised their results clearly by presenting a ruled table. The stronger candidates included the heading for percentage concentration of copper sulfate solution and the heading for number of drops of, **P**. The majority of candidates gained credit for recording the number of drops for each of the five concentrations of copper sulfate solution and for the results showing the correct trend (the higher the concentration of copper sulfate solution the more drops required). The majority of candidates recorded in whole drops.

(iii) Many candidates correctly described that, as the concentration of copper sulfate solution increased, the higher the concentration of hydrogen peroxide remaining in the test-tube.

(iv) The majority of candidates stated correctly that a source of error was that the drop size varied.

(v) The majority of candidates stated the number of drops needed to reach the end-point for **R**.

(vi) Many candidates used their results in **Question 1(a)(ii)** and **Question 1(a)(v)** to correctly estimate the concentration of copper sulfate in the sample of river water, **R**.

(b) (i) Most candidates used the headings given in **Table 1.3** to correctly label the *x*-axis (concentration of inhibitor / mg cm^{-3}) and the *y*-axis (percentage inhibition of sucrase). Some candidates labelled the incorrect axis or gave incomplete headings. For the *x*-axis, the stronger candidates used a scale of 0.5 to 2 cm and for the *y*-axis used a scale of 10 to 2 cm. Many candidates plotted all the points accurately and joined the points with a thin line. The most common error was not using the correct scale for the *y*-axis.

(ii) The majority of candidates drew two straight lines on their graph to show the concentration of inhibitor that caused 24% inhibition of sucrase. The stronger candidates took care to draw the line from the *y*-axis to meet the line on the graph precisely and then draw a straight line to cross the *x*-axis.

(iii) Many candidates correctly suggested that the inhibitor in green tea reduced the activity of the enzyme sucrase by binding to the enzyme's active site and changing its shape, preventing substrates from binding and reducing the number of enzyme-substrate complexes formed.

(iv) Some candidates correctly described how to determine the concentration of reducing sugars in a solution by first preparing at least five known concentrations of reducing sugars and then adding Benedict's solution to each concentration and heating to at least 80 °C. The time taken to the first colour change then needed to be recorded for each concentration. The stronger candidates correctly stated that the Benedict's test was carried out on the solution with the unknown concentration of reducing sugar and the time taken to first colour change was compared with the results for the known concentrations of reducing sugars.

Question 2

(a) (i) Credit was awarded to candidates whose drawings did not include any cells and used most of the space provided. The stronger candidates gained credit for carefully following the instructions, drawing the region of the leaf shown in **Fig. 2.1**, drawing the upper epidermis as three lines and the lower epidermis as two lines. The stronger candidates showed the correct proportion of the vascular bundle in relation to the depth of the midrib and showed subdivision of the vascular tissue. Many candidates used a label line and label to correctly identify the lower epidermis.

(ii) Credit was awarded to candidates whose drawings were made using a sharp pencil to produce thin lines which joined up precisely and used most of the space provided. Many candidates were able to draw a line of four adjacent xylem vessel elements, with each vessel element touching at least one other vessel element and with the walls drawn as double lines. The most common error was to draw lines that did not meet up precisely. Most candidates used a label line and label to identify the wall of a xylem vessel element.

(b) Many candidates stated differences using only observable features and listed three correct differences between the leaf on **M1** and the leaf in **Fig. 2.2**, such as: there were more vascular bundles on **M1** and fewer in **Fig. 2.2**, there were no trichomes present on **M1** while they were present in **Fig. 2.2** and the shape of the leaf on **M1** was straight while in **Fig. 2.2** the shape of the leaf was curled at the ends.

(c) Most candidates accurately measured the length of the scale bar and the length of the gap between the ends of the leaf, **D**–**E**, and used the appropriate units. Many candidates then correctly showed how to calculate the actual length of the gap by showing the length of **D**–**E** divided by the length of the scale bar and multiplied by 145 μm.

BIOLOGY

Paper 9700/35
Advanced Practical Skills 1

Key messages

Candidates should be given the opportunity to experience a variety of practical work throughout the course to develop the skills that can be applied to the requirements of the exam.

Candidates could be asked to suggest how to extend an investigation to answer a new question, for example by investigating a different independent variable. In this case, candidates were required to suggest how to modify the procedure to investigate the effect of substrate concentration on catalase activity. Candidates needed to show that the concentration of catalase was to be standardised and only one concentration used while the new independent variable, hydrogen peroxide concentration, was to be changed. Five different hydrogen peroxide concentrations were to be used to investigate the effect of substrate concentration on catalase activity.

Candidates should be encouraged to read the whole of each question before attempting it so that they can plan their time carefully and answer questions accurately.

General comments

In general, many candidates demonstrated that they had a good understanding of the skills required. There was good discrimination between the weaker and more able candidates and the majority of candidates showed that they were familiar with the use of the microscope.

Comments on specific questions

Question 1

(a) (i) Many candidates correctly completed **Table 1.2** by stating at least three concentrations of catalase (e.g. 75%, 50% and 25%) and stating the correct volumes of **E** and **W** to make up these concentrations.

(ii) The majority of candidates organised their results clearly by presenting a ruled table. The stronger candidates included the heading for the independent variable, percentage concentration of catalase, and the heading for the dependent variable, the number of drops. The majority of candidates gained credit for recording the number of drops for each of the five concentrations of catalase. Most candidates recorded the correct trend and recorded their results as whole drops.

(iii) Most candidates correctly described the trend according to their results.

(iv) Many candidates correctly explained that the higher the concentration of catalase the more active sites were available and consequently there was an increase in the number of enzyme-substrate complexes, producing more oxygen gas.

(v) The majority of candidates correctly stated that the independent variable was the concentration of catalase.

(vi) Many candidates correctly stated that one of the variables that was kept constant in the investigation was the volume of catalase. Other variables that were correct included the volume of hydrogen peroxide, the concentration of hydrogen peroxide and the time of 60 seconds.

(vii) Many candidates correctly identified two sources of error in step 7, such as the drop size varied and that the drops had already started being produced before the timing had been started.

(viii) Some candidates correctly described that the procedure could be modified to investigate the effect of substrate concentration on catalase activity by using at least five different concentrations of hydrogen peroxide and by using the same concentration of catalase.

(b) (i) Most candidates used the headings given in **Table 1.3** to correctly label the *x*-axis (concentration of salt solution / mmol dm^{-3}) and the *y*-axis (catalase activity / arbitrary units). Some candidates labelled the incorrect axis or gave incomplete headings. The stronger candidates used a scale of 100 to 2 cm for the *x*-axis and used a scale of 20 to 2 cm for the *y*-axis. Many candidates plotted all the points accurately and joined the points with a thin line.

(ii) Many candidates correctly estimated the concentration of salt solution at which the seed was germinated and showed on their graph how this figure was obtained.

Question 2

(a) (i) Credit was awarded to candidates whose drawings did not include any cells and used most of the space provided. The stronger candidates gained credit for carefully following the instructions and drawing the region indicated in **Fig. 2.1**. Many candidates gained credit for drawing at least three layers of tissue and the correct proportion of the vascular tissue in proportion to the size of the midrib. The stronger candidates showed subdivision of the vascular tissue and used a label line and label to correctly identify the cuticle.

(ii) Credit was awarded to candidates whose drawings were made using a sharp pencil to produce thin lines which joined up precisely and used most of the space provided. Many candidates were able to draw a line of four adjacent epidermal cells from the lower epidermis with each cell touching at least one other cell and with double lines representing the cell walls. The stronger candidates were credited for showing the correct shape of the epidermal cells. Most candidates used a label line and label to identify the cell wall.

(b) (i) Many candidates stated the correct number of eyepiece graticule units in 1.0 mm. The stronger candidates showed how to calculate the actual length of one eyepiece graticule unit by showing the division of 1000 by 45.

(ii) The majority of candidates correctly stated the number of eyepiece graticule units across the width of the leaf. Many candidates then used this figure to calculate the actual width of the leaf by multiplying this figure by the actual length of one eyepiece graticule unit from **Question 2(b)(i)** and showing the appropriate units, μm or mm.

(iii) Many candidates listed three correct observable differences such as the palisade layer on **N1** was thinner than in **Fig. 2.3** or that the size of the vascular tissue in proportion to the midrib on **N1** was larger than in **Fig. 2.3** or there were more vascular bundles on **N1** than were present in **Fig. 2.3**.

BIOLOGY

Paper 9700/37
Advanced Practical Skills 1

Key messages

Candidates should be given the opportunity to experience a variety of practical work throughout the course to develop the skills that can be applied to the requirements of the exam.

Candidates could be asked to suggest how to extend an investigation to answer a new question, for example by investigating a different independent variable. In this case, candidates were required to suggest how to modify the procedure to investigate the effect of temperature on the movement of water between the sodium chloride solution and the cells in the plant tissue. Candidates needed to show that the length of the potato tissue was to be standardised and only one length used while the new independent variable, temperature, was to be changed. Candidates also needed to show that at least five different temperatures were to be used to investigate the effect of temperature on the movement of water.

Candidates should be encouraged to read the whole of each question before attempting it so that they can plan their time carefully and answer questions accurately.

General comments

Candidates who have used materials and apparatus during practical work as part of the course are likely to perform better in the exam. Whilst the activities in the exam may not be familiar, candidates who have had the opportunity to follow instructions carefully in a variety of practical work are likely to find it easier to organise and complete unfamiliar activities.

In general, many candidates demonstrated that they had a good understanding of the skills required. There was good discrimination between the weaker and more able candidates and the majority of candidates showed that they were familiar with the use of the microscope.

Comments on specific questions

Question 1

(a) (i) The majority of candidates stated the diameter of one cylinder of plant tissue and calculated the radius correctly and used the appropriate units, mm or cm.

(ii) Most candidates stated the volume of **S** that was put into each beaker and gave a reason for the volume used, such as to completely submerge the plant tissue.

(iii) Many candidates completed **Table 1.3** by correctly calculating the surface area of one piece of plant tissue and the total surface area of the whole piece of plant tissue for n = 1 and h = 40 as well as n = 16 and h = 2.5. The most common error was using the radius measured in cm rather than mm.

(iv) The majority of candidates correctly stated that the total surface area increased when one whole cylinder was cut into 16 smaller pieces.

(v) The majority of candidates organised their results clearly by presenting a fully ruled table. The stronger candidates included an appropriately detailed heading for the independent variable (number of pieces) and the dependent variable (length with appropriate units, mm or cm). The most common errors were stating that the heading for the independent variable was ‘beaker’ or to

include 'mm' in the body of the table. The majority of candidates gained credit for recording the lengths as whole millimetres or whole centimetres or to the nearest 0.5 cm. The stronger candidates recorded the correct trend, showing that the higher the number of pieces the shorter the total length.

(vi) Many candidates described the correct trend, according to their results, with reference to the total surface area and the total length of the cylinders.

(vii) A few candidates correctly explained the trend in their results by referring to the increased surface area in contact with the sodium chloride solution and the shorter distance for diffusion to take place from the solution to the centre of the potato cylinders.

(viii) Many candidates correctly stated a source of error in the investigation when measuring the dependent variable by describing the difficulty of lining up the cylinders and trying to avoid gaps between the potato pieces when measuring the total lengths.

(ix) Some candidates correctly suggested that using one length of plant tissue and at least five different temperatures would be suitable modifications to the procedure so that the effect of temperature on the movement of water between the solution and the cells in the plant tissue could be investigated.

(b) (i) The majority of candidates drew the graph using the headings given in the table, with percentage concentration of sodium chloride on the *x*-axis and percentage number of whole red blood cells on the *y*-axis. The stronger candidates used scales of 0.2 to 2 cm for the *x*-axis and 20 to 2 cm for the *y*-axis, plotted the points exactly with a small cross or dot in a circle and drew a sharp, ruled line accurately connecting each of the points. The most common errors were not including a full label for each axis, not labelling the scale every 2 cm, plotting points which were not circled, and drawing lines which did not go through the plotted points exactly.

(ii) Many candidates correctly stated that 0.9% sodium chloride solution had the same water potential as the red blood cells.

(iii) Many candidates correctly explained that the effect of 0.4% sodium chloride solution on red blood cells was that water entered the red blood cells as the water potential of the sodium chloride solution was high and the water potential of the cells was low.

Question 2

(a) (i) The stronger candidates produced drawings using a sharp pencil to draw clear, sharp lines which joined up precisely, did not include any shading and used most of the space provided. Many were able to draw the epidermis as a double line with at least two layers of tissue within the stem. Many candidates drew at least two vascular bundles which were subdivided into at least three areas. The most common error was not showing all the different tissues and their correct distribution, which would be observable using the microscope. Most candidates used a label line and label to correctly identify the phloem in the top half of the vascular bundle.

(ii) Credit was awarded to candidates whose drawings were made using a sharp pencil which joined up precisely, did not include any shading and used most of the space provided. The majority of candidates gained credit for drawing a line of four xylem vessel elements, each touching at least one other vessel element and at least two vessel elements with more than four sides. Most candidates used a label line and label to identify the lumen.

(b) (i) Many candidates correctly calculated the actual length of one eyepiece graticule unit by dividing 0.1 mm by 40 and showing the answer as 2.5 μm.

(ii) Many candidates correctly stated that the section of vascular tissue **T** was equivalent to 26 eyepiece graticule units and then multiplied this number by their answer to **Question 2(b)(i)**. The stronger candidates included the appropriate units with their actual length of the vascular tissue **T**.

(c) (i) Many candidates listed three correct observable differences between the stem on **L1** and the stem in **Fig. 2.3**, such as the position of the vascular bundles on **L1** being located in a ring close to the epidermis and the vascular bundles being scattered in **Fig. 2.3** or all the vascular bundles on **L1**

being a similar size while those in **Fig. 2.3** were either large or small and the xylem vessels arranged in a line on **L1** while the xylem vessels were scattered in **Fig. 2.3**.

(ii) Many candidates correctly identified the plant organ on **L1** and in **Fig. 2.3** as a stem and stated the observable feature that helped to identify the plant organ, such as stems have dispersed vascular bundles (in roots, the vascular bundles reside within the central core). Other answers were also acceptable and were credited.

BIOLOGY

Paper 9700/38
Advanced Practical Skills 2

Key messages

Candidates should be given the opportunity to experience a variety of practical work throughout the course to develop the skills that can be applied to the requirements of the exam.

Candidates should learn the methods for testing biological molecules as specified in the syllabus, such as the Benedict's test. The volume of Benedict's solution must be the same or more than the volume of the sample being tested and the temperature of the water bath should be at least 80 °C and up to 100 °C. In this case, the candidates were required to determine the concentration of reducing sugars in a solution. Candidates needed to show that at least five known concentrations of reducing sugars were to be prepared and then tested with Benedict's solution, recording the time to the first colour change for each concentration. The solution with the unknown concentration of reducing sugar would also be tested with Benedict's solution and the time to first colour change compared to the results for the known concentrations to estimate the concentration of reducing sugars in the solution.

Candidates should be encouraged to read the whole of each question before attempting it so that they can plan their time carefully and answer questions accurately.

General comments

Candidates who have used materials and apparatus during practical work as part of the course are likely to perform better in the exam. Whilst the activities in the exam may not be familiar, candidates who have had the opportunity to follow instructions carefully in a variety of practical work are likely to find it easier to organise and complete unfamiliar activities.

In general, many candidates demonstrated that they had a good understanding of the skills required. There was good discrimination between the weaker and more able candidates and the majority of candidates showed that they were familiar with the use of the microscope.

Comments on specific questions

Question 1

(a) (i) Most candidates were able to show how to prepare a serial dilution, showing the correct concentration below each beaker, 0.50%, 0.25%, 0.125% and 0.0625%, and transferring 10 cm^3 of the previous concentration to the next beaker and adding 10 cm^3 of distilled water to each beaker.

(ii) The majority of candidates organised their results clearly by presenting a ruled table. The stronger candidates included the heading for percentage concentration of copper sulfate solution and the heading for number of drops of, **P**. The majority of candidates gained credit for recording the number of drops for each of the five concentrations of copper sulfate solution and for the results showing the correct trend (the higher the concentration of copper sulfate solution the more drops required). The majority of candidates recorded in whole drops.

(iii) Many candidates correctly described that, as the concentration of copper sulfate solution increased, the higher the concentration of hydrogen peroxide remaining in the test-tube.

(iv) The majority of candidates stated correctly that a source of error was that the drop size varied.

(v) The majority of candidates stated the number of drops needed to reach the end-point for **R**.

(vi) Many candidates used their results in **Question 1(a)(ii)** and **Question 1(a)(v)** to correctly estimate the concentration of copper sulfate in the sample of river water, **R**.

(b) (i) Most candidates used the headings given in **Table 1.3** to correctly label the *x*-axis (concentration of inhibitor / mg cm^{-3}) and the *y*-axis (percentage inhibition of sucrase). Some candidates labelled the incorrect axis or gave incomplete headings. For the *x*-axis, the stronger candidates used a scale of 0.5 to 2 cm and for the *y*-axis used a scale of 10 to 2 cm. Many candidates plotted all the points accurately and joined the points with a thin line. The most common error was not using the correct scale for the *y*-axis.

(ii) The majority of candidates drew two straight lines on their graph to show the concentration of inhibitor that caused 24% inhibition of sucrase. The stronger candidates took care to draw the line from the *y*-axis to meet the line on the graph precisely and then draw a straight line to cross the *x*-axis.

(iii) Many candidates correctly suggested that the inhibitor in green tea reduced the activity of the enzyme sucrase by binding to the enzyme's active site and changing its shape, preventing substrates from binding and reducing the number of enzyme-substrate complexes formed.

(iv) Some candidates correctly described how to determine the concentration of reducing sugars in a solution by first preparing at least five known concentrations of reducing sugars and then adding Benedict's solution to each concentration and heating to at least 80 °C. The time taken to the first colour change then needed to be recorded for each concentration. The stronger candidates correctly stated that the Benedict's test was carried out on the solution with the unknown concentration of reducing sugar and the time taken to first colour change was compared with the results for the known concentrations of reducing sugars.

Question 2

(a) (i) Credit was awarded to candidates whose drawings did not include any cells and used most of the space provided. The stronger candidates gained credit for carefully following the instructions, drawing the region of the leaf shown in **Fig. 2.1**, drawing the upper epidermis as three lines and the lower epidermis as two lines. The stronger candidates showed the correct proportion of the vascular bundle in relation to the depth of the midrib and showed subdivision of the vascular tissue. Many candidates used a label line and label to correctly identify the lower epidermis.

(ii) Credit was awarded to candidates whose drawings were made using a sharp pencil to produce thin lines which joined up precisely and used most of the space provided. Many candidates were able to draw a line of four adjacent xylem vessel elements, with each vessel element touching at least one other vessel element and with the walls drawn as double lines. The most common error was to draw lines that did not meet up precisely. Most candidates used a label line and label to identify the wall of a xylem vessel element.

(b) Many candidates stated differences using only observable features and listed three correct differences between the leaf on **M1** and the leaf in **Fig. 2.2**, such as: there were more vascular bundles on **M1** and fewer in **Fig. 2.2**, there were no trichomes present on **M1** while they were present in **Fig. 2.2** and the shape of the leaf on **M1** was straight while in **Fig. 2.2** the shape of the leaf was curled at the ends.

(c) Most candidates accurately measured the length of the scale bar and the length of the gap between the ends of the leaf, **D**–**E**, and used the appropriate units. Many candidates then correctly showed how to calculate the actual length of the gap by showing the length of **D**–**E** divided by the length of the scale bar and multiplied by 145 μm.

BIOLOGY

Paper 9700/41
A Level Structured Questions

Key messages

Candidates need to be accurate in their use of subject-specific and scientific terms, including basic chemistry terms like molecule, ion and inorganic. A level Biology involves vocabulary to describe the structures and processes studied and candidates should learn spellings of subject-specific terms carefully. It is important that spellings are accurate enough for the word intended to be discerned.

Candidates should be precise in describing scientific phenomena and avoid vague words such as 'affect', 'alter' and 'change' as generally the effect itself, such as an increase or decrease, needs to be described. Another vague term for candidates to avoid is 'involve' as the way in which something is involved, for example as a reactant or product, being used or being produced, is needed. Candidates should also be discouraged from using the word 'favoured' instead of stating that a certain phenotype is selected for or has a selective advantage, as in **Questions 5**.

Many candidates would benefit from reading through their answers to check that terminology has been used correctly. For example, check that ions are named as such (e.g. sodium ion, not just the symbol denoting the element sodium), that ion symbols are correct and that quoted figures have complete and correct units.

General comments

Some candidates were well prepared with clear knowledge of the subject matter and demonstrated the requisite A level skills of clear written communication of scientific facts and ideas. Weak scripts showed poor skills in written English, limited knowledge, and answers were often a collection of ideas and irrelevant facts that were not coherently linked to form a logical answer to the question. The AO2 component of the exam means that simply recalling a list of facts related to a key word in the question will not necessarily provide an adequate answer. Candidates who could analyse the meaning of the question stem material, data and question command wording dealt successfully with AO2 questions and achieved high marks overall.

The best-known topics were respiration, photosynthesis and natural selection, and the best-answered questions were those requiring a one-word answer such as a classificatory term or part of the kidney nephron.

Comments on specific questions

Question 1

(a) Most answers named glucose as a molecule entering the respiration pathway to synthesise ATP. Correct second answers named suitable small molecules that directly enter the respiration pathway, such as amino acids, fatty acids and glycerol and respiratory pathway intermediates. Terms denoting general categories like carbohydrates were ignored, as were polymers that need to be broken down before entering the respiration reaction pathway of glycolysis, link reaction or Krebs cycle.

(b) The best answers focused on the central point that ATP is broken down into ADP and phosphate to yield energy, and that the process is reversible so energy from respiration can be harnessed to reassemble ATP for next use. The question stem at the top of **Question 1** modelled the correct way to describe 'release of energy'. It is acceptable to state energy is released, given out or provided by the hydrolysis of ATP. It is not correct to state energy is produced, made, formed or created (since the law of conservation of energy states that energy cannot be created or destroyed,

only transformed from one form to another). One common error was the idea that ATP travels in the blood or around the body. ATP is made and used within individual cells. Candidates frequently referred to 'turnover' without showing full understanding of what this means, that the reaction of ATP to ADP plus inorganic phosphate is reversible, and that cycles of hydrolysis and synthesis of ATP occur within a cell.

Some candidates made errors in distinguishing between ATP synthase (the enzyme that joins ADP and Pi to form ATP) versus ATPase or ATP hydrolase (the enzyme that catalyses the reverse reaction of breaking down ATP).

(c) Most answers correctly stated substrate-linked (or substrate-level) phosphorylation. Incorrect answers included oxidative phosphorylation and photophosphorylation.

(d)(i) Around half the candidates correctly named oxygen as the inorganic molecule, the presence of which means pyruvate enters the matrix. Many candidates needed to note the term 'inorganic' as they named organic molecules such as acetyl coenzyme A and NAD.

(ii) Answers generally focused on the relevant areas of biology but many candidates did not explicitly answer the question about how ATP yield is affected, i.e. that presence of oxygen increases the yield. Candidates who did not name oxygen in **Question 1(d)(i)** frequently obtained some or all of the credit for relating their suggestion to the electron transport chain, proton gradient and chemiosmosis.

Question 2

(a) Descriptions of how the experimental set-up allowed rate of respiration to be determined were often vague and sometimes inaccurate, revealing a lack of understanding of the materials used and principles involved. The strongest answers covered the role of the sodium hydroxide in absorbing the carbon dioxide produced by woodlice, leaving the oxygen use as a source of reduced pressure in the apparatus that drew the droplet of liquid towards the woodlice. The basic observation that needed to be recorded was the distance moved by the drop in a set time, or the time taken for the drop to move a certain distance. Answers were more successful in explaining how to calculate rate and how to convert the distance measurement to the volume of oxygen used than in explaining the principles on which the apparatus works.

Some candidates showed little knowledge about how the apparatus worked to measure respiration rate and made many incorrect suggestions.

(b) Some predictions needed to state whether they related to 5 °C or 20 °C. Correct predictions were not always supported by a precise argument that related to kinetic energy or to the frequency of enzyme-substrate collisions.

Question 3

(a) Almost half the candidates correctly deduced that the allele was dominant. Some who named the disease allele as being dominant could have made greater use of the pedigree diagram with reference to individuals 2 (normal father) and 3 (daughter with the disease) to explain their conclusion. Some who realised the allele was dominant mistakenly referred to heterozygous female 1 as a 'carrier'. Answers that did not make the correct deduction mostly either stated incorrectly that the allele was recessive or focused on the sex linkage aspect, despite being asked to draw one conclusion other than the fact inheritance was sex-linked. As this is a genetic disease, people with the disease are described as being affected, not infected.

(b) Strong answers named this as an example of the founder effect, since some individuals in the 100 Dutch settlers had or carried the disease, and by chance this was a greater frequency than in the original source population. Subsequent inbreeding reinforced the over-representation of the disease allele in the founding population. Weaker answers that suggested more implausible events such as a mutation or selection pressure for porphyria needed to be specific about when the hypothesised mutation occurred or where the supposed selection pressure acted to gain credit. Candidates who focused on possible differences in modern medical care in Europe and South Africa were not focusing on the 400-year historical context of this question.

Many candidates referred to the Dutch settlers 'interbreeding amongst themselves'. Where a particular group breed together repeatedly this is inbreeding. The term interbreeding should be used for breeding between two different groups. Answers such as 'they interbred' therefore did not gain credit, whereas reference to inbreeding occurring did.

(c) Many candidates had learned the principles of a microarray. Fully correct answers started with mRNA, not DNA, since this question was about gene expression. The complementary single-stranded cDNA then needs to be separated from the mRNA before hybridising with single-stranded DNA probes. Errors occurred in how candidates described the order of events (e.g. hybridising before the sample DNA had been tagged), the terminology used (primers and promoters on the microarray chip instead of probes) and in basic understanding (a marker gene such as GFP or a fluorescent protein being added to the sample DNA instead of a fluorescent DNA-binding dye). Some answers added the unnecessary step of making the cDNA double-stranded before then denaturing it to get back to a single-stranded molecule. Weaker answers listed partial vague steps in the process, e.g. 'wash the DNA' rather than specifically wash off the unbound sample cDNA from the chip after hybridisation.

The most common error was equating a marker gene (section of DNA that codes for a fluorescent protein when expressed in a living cell) with a fluorescent tag (a dye that binds to a DNA molecule and glows under ultraviolet light).

(d) The word 'database' triggered some generic answers about bioinformatics that did not answer this specific question. Here the use of the database is to compare a patient's DNA sequence for correct diagnosis to choose the appropriate treatment.

(e) Answers frequently made at least one valid point: identifying the base change required or focusing on the specificity of the guide RNA (gRNA), or speculating that the functional enzyme produced after gene editing perhaps breaks down porphyrins. Stronger answers made all of these points. Some candidates did not attempt to answer this question.

Question 4

(a) Most candidates could identify three similarities. Three simple statements beginning 'Both have…', 'both use…' or 'both produce…' were the clearest way to display correct answers. Some candidates misused the terms reactant and product. In photosynthesis the substances used, such as carbon dioxide and water, are reactants and a substance produced, such as oxygen, is a product. An answer that stated 'both processes use the product carbon dioxide' contradicted itself and was incorrect.

(b) Most candidates identified **B** correctly as a thylakoid membrane (or lamella or part of a granum) with fewer recognising structure **A** as a starch grain.

(c) (i) Most named the correct products, although some answers included additional incorrect molecules that negated the answer. The commonest error was to state 'reduced NAD' instead of 'reduced NADP'.

(ii) Most candidates answered well, explaining the roles of proteins such as ATP synthase, the carriers of the electron transport chain and the oxygen-evolving complex. Some candidates were incorrect in suggesting that photosynthetic pigments are proteins. A few candidates mentioned the role of proteins in scaffolding the pigments within the light-harvesting complexes in the membrane. There was some confusion between ATP synthase and ATPase in some weaker answers.

(d) Most candidates correctly named triose phosphate or TP. Incorrect answers included GP and pyruvate.

(e) Candidates needed to think creatively, building on a baseline of syllabus knowledge. The most common correct point was the potential ability of solar panels to store energy, allowing the artificial photosynthesis process to continue in the dark. Some candidates made sensible comparisons between the relative amount or range of wavelengths of light that might be harvested by solar panels or leaves, or the different impact of limiting factors or energy transduction losses on the two processes.

Question 5

(a) (i) Most recognised the increase in mean bill size after the drought as directional selection. Incorrect answers included stabilising, environmental and destructive.

(ii) Almost half the curves were drawn correctly and showed the curve shifted entirely to the right. Some candidates missed out this question where the answer was expected on the graph and not on a dotted line. Curves needed to start and end on the *x*-axis.

(b) Well-prepared candidates gave full answers explaining how disruptive selection had resulted in the bimodal distribution shown on **Fig. 5.3**. A complete answer identified the selection pressure (seed or food availability or size), the finch phenotypes that were selected for (those with large and small beaks) and those that were selected against (birds with beaks of medium or intermediate size). These responses also commented on how this selection affected allele frequencies (an increase in the alleles for large and small beaks or a decrease in the alleles for intermediate-size beaks). Vague answers about the environment 'favouring' certain phenotypes did not score, and in answers where it was stated that the birds with medium beaks were 'favoured against' it was apparent that the word 'favoured' was not understood. Candidates should be encouraged to use the terminology of selection pressure and selection for or against different phenotypes, or to outline which phenotypes are more or less likely to survive and reproduce. Weaker answers sometimes stated that different-sized seeds were undergoing natural selection, as opposed to birds, or that there was selection for one phenotype only instead of two. Incorrect spellings for disruptive included 'destructive', 'disruptional', 'disrupting' and 'distruptive'.

(c) (i) Most candidates selected the correct critical value for five observations at probability 0.05 for their answer. Some candidates chose an incorrect value or did not know that *r* had to be greater than the critical value for the result to be significant. Some did not refer to or make use of **Table 5.1**.

(ii) Many candidates described four ways in which invasive alien species could have negative effects on an ecosystem. Candidates who described the effects on specifically the native, local, indigenous, original or pre-existing species were most successful in making their points about competition and predation. While alien species may change the habitat, for example by overgrazing, changing soil pH, eroding soil or creating shade, arguments that implied they caused 'habitat loss' for other species by simply occupying space were not accepted. It was common for candidates to confuse the words disturb and disrupt with various hybrid spellings that may not be clear in certain contexts.

(iii) In the context of other factors causing extinction, habitat loss (or habitat degradation or destruction) was accepted. Other popular correct answers were climate change, pollution, disease and hunting by humans. Hunting by itself was not a sufficient answer since natural predators within a habitat also hunt, and this may play a key role in regulating population sizes in a stable food web.

Question 6

(a) (i) Candidates frequently named the processes at **P** (selective reabsorption) and **R** (ultrafiltration) correctly; fewer answers identified **Q** as osmoregulation or homeostasis. Some candidates did not follow the instructions in the question and named diffusion, osmosis and active transport, which were not credited.

(ii) Structures **P** (proximal convoluted tubule) and **Q** (collecting duct or distal convoluted tubule) were best known. **R** was less often correctly identified as Bowman's capsule.

(b) Many candidates realised that **B** contains more salt, but few related this to the salt gradient that is established to allow the collecting duct to reabsorb water along its entire length.

Question 7

(a) Many candidates gave similar answers to both **Question 7(a)** and **Question 7(b)(i)**. **Question 7(a)** required the principles of what cell signalling molecules do, such as travel in the blood and act as a ligand by binding to receptors on target cells to cause a response. Creditable answers could be general, such as a stimulus causes insulin to be released from an endocrine gland, or specific, naming the stimulus and gland. Many answers went into detail about G protein-linked signal amplification within the cell and, while this was not penalised (although insulin does not operate

using this system), it sometimes meant the answer omitted other more relevant points about insulin secretion, movement, binding to receptors and effects on target cells.

(b) (i) The graphs for meal A showed insulin rising and falling in a similar pattern to blood glucose concentration and here the question focus was on insulin's role in achieving negative feedback of blood glucose concentration. Strong answers explained that a rise in blood glucose concentration was detected and this resulted in insulin being secreted which caused the blood glucose concentration to fall again, reversing the change and achieving homeostasis, to keep blood glucose concentration within a normal range. Some candidates gained credit for reading the graph accurately to quote figures with units to support their answer. It is clearer for candidates to specify whether a concentration is increasing or decreasing to get back to the normal range, rather than just state that it is changing or returning back to normal. The addition of more GLUT proteins to the cell membrane of a liver cell increases the cell's permeability to glucose, not its permeability 'of' glucose.

The pancreas gland is frequently misspelt as 'pancrease' which is not acceptable. The specific cells that secrete insulin are the beta cells, and if beta is written as a symbol it needs to be recognisable as the letter beta (β) with a tail, and not as a capital 'B'. The exact spellings and meanings of the following words need to be carefully learned: the polymer glycogen, the polymer-forming process glycogenesis and the enzyme that catalyses this reaction called glycogen synthase.

(ii) Many answers simply observed that as there was little carbohydrate in meal B, little insulin was secreted. More thoughtful responses attributed the fall in mean blood glucose concentration to respiration, and the subsequent rise in the secretion of glucagon resulting in glycogenolysis or gluconeogenesis.

It is crucial that the spelling of the hormone glucagon is fully correct to distinguish it from the polymer glycogen. A single vowel changed in either of them can make the intended meaning unclear. Some candidates confused glycogenolysis, which produces glucose, and glycolysis, which breaks it down. The correct term for the conversion of fat and protein substrates to glucose is gluconeogenesis.

Question 8

This question asked about the role of gibberellin in stem elongation. Candidates were generally knowledgeable about hormone-receptor binding triggering destruction of DELLA proteins to release a transcription factor. It was not generally known that the gibberellin receptor is intracellular. Some answers misnamed the DNA promoter of a gene as the operator, which is a term used for a section of DNA in prokaryotic operons that is not used in the context of eukaryotic genomes like those of plants. Weaker candidates were confused about what was binding to what, for example, stating that gibberellin bound directly to DELLA or that DELLA or PIF bound to RNA polymerase to start transcription.

Strong answers made it clear that either PIF, a transcription factor, or RNA polymerase bound to the DNA or promoter to begin transcription and also named an appropriate gene whose product would contribute to stem elongation, such as a gene for growth or the XET gene. The switching on of amylase production that occurs during seed germination is not appropriate in the context of gibberellin triggering stem elongation. Some excellent answers linked XET or expansins to the breaking of bonds between cell wall components like cellulose microfibrils, allowing water entry by osmosis into the cells that make up the stem, resulting in cell elongation and an overall increase in stem internode length. Gibberellins may interact with auxins to give this effect but candidates who stated that gibberellin signalling switches on the 'gene for auxin' had forgotten that auxin is not a protein, so there is no 'gene for auxin'.

Question 9

(a) Many candidates could name the two prokaryotic domains as Archaea and Bacteria, although the spelling of Archaea was often too poor for credit to be awarded. The most frequently mentioned difference between them was the presence or absence of a peptidoglycan cell wall, and many answers also referred to the presence or absence of histones. Many candidates referred to the difference in ribosomes or rRNA but some were mistaken in thinking that Archaea have 80S ribosomes instead of 70S. There were many partial answers referring to membranes or lipids and ether and ester bonds, but a full answer needed to reference ester-linked membrane lipids in one

(Bacteria) and ether-linked membrane lipids in the other (Archaea) or just a difference in membrane lipids.

(b) Most candidates gained some credit here for naming the Eukarya domain, the kingdom Animalia and the genus *Panthera*. Errors included writing the genus name without a capital '*P*' and including the specific name *tigris* as well.

Question 10

(a) Many candidates did very well on this question. They recognised the potential difference values at **X**, **Y** and **Z** as corresponding to resting potential, the peak of the action potential and hyperpolarisation respectively, and they structured their answers to clearly name **X**, **Y** and **Z** and to describe the events that led up to or occurred at each of these time points. A tiny minority of answers did not refer to **X**, **Y** and **Z** or the potential difference values measured at these time points, and without this structuring these answers were unable to gain any credit. Generally, the ion channel opening and ion movements associated with depolarisation and hyperpolarisation were better explained than the more complex events involving the sodium-potassium ion pump and leak channels allowing different rates of diffusion that combine to establish resting potential.

Some answers used the word pump when instead they meant channel or stated that ions were pumped through channels when in fact ions move through voltage-gated channels by diffusion according to the concentration gradients previously established. Candidates frequently misused the term 'threshold', often stating wrongly that the peak of the action potential at +40 mV is the 'threshold potential'. Basic chemistry terms were misused by some weaker candidates, who called sodium ions 'sodium molecules' or gave ions the wrong symbols (e.g. NA instead of Na) or the wrong charges (e.g. Na^{2+} instead of Na^{+}).

(b) Around half of the candidates wrote inappropriately about nodes of Ranvier, even though the question referred to an unmyelinated neurone. Correct answers stated local circuits occurring and described how sodium ions that enter at one point along the axon are attracted to the negatively charged adjacent area within the neurone that is still at resting potential, moving sideways along the axon and reversing the charge at the new point, triggering the opening of more sodium ion voltage-gated channels.

(c) Candidates finished strongly with this question about the advantages of a myelin sheath, with many gaining full credit. 'Faster transmission' needed to be qualified by identifying what is transmitted faster in a myelinated neurone, such as the impulse or action potentials (plural). Saltatory conduction was often named or described well, and some answers mentioned the advantage of faster responses for the vertebrate.

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Key messages

Candidates should take care to note what the command word is asking them to do, so that they answer the question precisely and do not spend time giving unnecessary information. For example, in **Question 10(a)**, instead of suggesting reasons for the change in blood lactate concentration, many candidates simply described the graph.

It is important for candidates to have experience of using methods stated in the learning outcomes of the syllabus rather than learning them theoretically. For example, for **Question 9(a)**, the use of a frame quadrat is included in learning objective 18.2.4 and candidates are expected to have used these methods.

General comments

Many candidates scored well in this paper. Several of the questions involved novel contexts, to which many were able to give clear and full answers. Almost all candidates completed all of the questions on the paper

Comments on specific questions

Question 1

(a) (i) The majority of candidates did not correctly identify the carrier that received the hydrogen atoms from reduced FAD. Many candidates provided more than one letter in a list.

(ii) This aspect of respiration was well known and the majority of candidates were confident in describing the events concisely and accurately. Some incorrectly named the process of proton movement as diffusion or moved the protons to an incorrectly named part of the mitochondrion. There were other correct descriptions of the proton gradient given such as an electrochemical gradient, concentration gradient and proton motive force.

(iii) Candidates were able to demonstrate their knowledge of oxidative phosphorylation here with the majority gaining all or most of the credit. Most candidates were able to identify structure **5** as ATP synthase, although a few incorrectly gave ATPase. Most correctly stated that protons moved into the matrix, and some were able to identify facilitated diffusion for further credit.

(b) There were varied responses to this question, with many candidates able to score highly. All marking points were seen regularly. Candidates answered from several different starting points and generally demonstrated confidence in their knowledge and ability to apply their ideas to the novel context of cyanide as an inhibitor. Most candidates were able to identify a reduction in proton gradient and ATP production. Where candidates listed glycolysis alongside the (correct) stages of aerobic respiration, credit was not given for this point. Fewer candidates successfully referred to the effects on oxygen as a final electron acceptor, and a smaller number stated the impact on NAD/FAD regeneration.

Question 2

Candidates found this question on genetic drift and the founder effect challenging. The strongest answers were clearly set out in two sections – one for genetic drift and one for the founder effect.

There was a great deal of confusion with both genetic drift and the founder effect being confused with the effects of natural selection, speciation and small populations undergoing inbreeding. Some candidates gave answers that suggested genetic drift and the founder effect were the same thing.

Both processes occur due to a chance event and are not caused by selection. In the chance event, it is possible that alleles are lost from the gene pool, so that for one specific gene locus when an allele is lost, a different allele would increase in frequency. A loss of alleles would result in a decrease in the gene pool. The strongest candidates were able to explain these points carefully enough to be credited. Many candidates introduced selection and allele frequencies changing due to the presence of an advantageous allele. Some recognised that this would mean an increase in homozygosity but conflated this with a result of inbreeding in a small population, not as the result of an allele being lost from the gene pool. Some candidates incorrectly suggested a whole gene would be lost from the genome.

Chance events were rarely qualified. A minority of candidates recognised events that could lead to genetic drift, for example: fusion of gametes, reproduction, death or mutations. Some incorrectly linked a selection pressure to causing the mutation that caused the genetic drift. Many candidates identified the relevance of a small population but usually incorrectly stated that genetic drift only happened in small populations instead of its effect being more pronounced in smaller populations.

A greater number of candidates were successful when explaining the founder effect by identifying that a small number of individuals became isolated. Many candidates needed to convey the idea of a small population breaking away from a larger population; many wrote about an inability to breed with the original population. Often a cause of the founder effect was given as a named disaster. A good number of candidates were also able to explain that not all alleles would be present in the new founder population when compared to the original population. Some also referenced the bottleneck effect. The main area of incorrect biology was around the topic of speciation, especially allopatric speciation involving a geographical isolating mechanism. Many responses mentioned inbreeding and inbreeding depression, hybrid vigour and adaptations to different environments. Terms such as species, population and individuals were often interchanged. This often meant the chosen term was used incorrectly in a given context.

Question 3

(a) (i) There were numerous entirely correct answers, in which a clearly set out genetic diagram was given. The genotypes of the parents were shown, then a Punnett square was set out with the correct gametes, and the genotypes and phenotypes of the offspring written within the square. From this, the ratio of the two phenotypes could be determined. Some candidates, however, gave the 15:1 ratio, but did not state which phenotypes this referred to.

Some candidates who gave otherwise correct answers did not give the phenotypes associated with each genotype. This is most easily done by writing the phenotype in the Punnett square immediately beneath each genotype. A slightly different method, used by some candidates, was to give a key that clearly showed this – for example, a circle to represent with awn, and a cross to represent without awn, written in the Punnett square next to each genotype.

A significant proportion of candidates incorrectly showed the cross between the first pair of parents, rather than the cross between the F1 generation to produce the F2 generation.

Many candidates were unable to construct a genetic diagram for a dihybrid cross. Gametes with genotypes containing two alleles of the same gene – for example, Aa or bb – were often seen.

(ii) Very few candidates were able to deduce the type of inheritance shown in **Question 3(a)(i)** to give the correct term as epistasis or autosomal dominant. Incorrect responses included: dominant dihybrid, codominance, mixed inheritance and dihybrid linkage.

(b) Many candidates were able to make a reasonable suggestion of how the awn might provide an advantage to wild rice. The most commonly seen acceptable suggestions were that it would allow the grain to stick to the fur of animals, or to catch the wind and so allow the grain to disperse further. A common error was to write about the awn helping in pollination rather than seed dispersal. Candidates also incorrectly referred to herbivores as predators.

(c) (i) There were many good answers here, with most candidates recognising that the farmers would have done this using selective breeding (or artificial selection). Answers then often correctly described the selection of plants that produced grains with awns, breeding these plants together,

and then collecting the grains and planting them to produce the next generation of plants. Quite a few answers incorrectly stated that the farmers would breed the grains together, rather than the plants. Most knew that the process would have been continued for several generations.

A fairly common error was to suggest that the farmers would have selected the rice by genotype, rather than phenotype. Some candidates also thought the farmers might have used genetic engineering, the descriptions of which were generally very muddled and inappropriate – for example, attempting to describe gene therapy.

(ii) The strongest answers were generally quite short and concise. These candidates were able to demonstrate their understanding of how a change in the nucleotide sequence of a gene can affect its product, and of how transcription factors affect gene expression. They recognised that a change at the *An-1* locus meant that a mutation had happened, or that there had been a change in the base or nucleotide sequence. They went on to explain that this would result in a non-functional transcription factor or none at all, which would not bind to the promoter and therefore that the expression of the gene for awn development would decrease and the expression of the gene for number of grains produced would decrease.

There were numerous weaker answers that were based on the ways in which scientists could make a change at the *An-1* locus, for example, by gene editing, which the question did not ask for. There were numerous instances of DNA being made up of a sequence of amino acids, or the transcription factor being a gene. Quite a few candidates became confused with operons when trying to explain the effect of having a transcription factor that could not bind with the DNA.

Question 4

(a) Many candidates recognised that gametes are haploid and that their fusion at fertilisation creates a diploid cell with two sets of chromosomes. They were also able to explain that one of these sets of chromosomes comes from each parent and that each maternal chromosome has a homologous paternal chromosome that shares the same gene loci.

Frequent errors included confusing haploid and diploid or attempting to describe mitosis or meiosis. The fact that a diploid cell contains two sets of chromosomes was often omitted from answers. It is helpful for candidates to learn to think of haploid and diploid in terms of how many sets of chromosomes are present in a cell, rather than just the number of chromosomes. Many answers implied that every diploid cell has 46 chromosomes, or that haploid cells contain a 'half set' of chromosomes while a diploid cell has a 'full set'.

A significant number of answers wrongly suggested that, after fertilisation, chromosomes (or chromatids) from the two gametes join together, forming the two chromatids of a chromosome. Further incorrect ideas were that the chromosomes from the male and female gametes are only said to be homologous when they have paired up with each other.

(b) Very few candidates knew at which stage in meiosis reduction division occurs, with many opting for the separation of sister chromatids in meiosis II, rather than homologous chromosomes. Many candidates also named a stage but without reference to the first or second division of meiosis. Some opted for cytokinesis, which is not considered a distinct stage in meiosis, but an event of telophase I and/or telophase II.

(c) (i) Candidates are required to be able to identify the main stages of meiosis through interpretation of photomicrographs of cells in different stages, which aligns with knowledge of the behaviour of chromosomes during meiosis. This forms a key practical skill, demonstrating that candidates can apply theoretical knowledge from textbooks. The stages of meiosis were not identified correctly in most cases, with many confusing meiosis I and meiosis II, or omitting giving either.

(ii) This question tested candidates' understanding of the terms chromatids and chromosomes, and their precise use. Working backwards, candidates should know that a single chromatid has a sister chromatid that it separates from in meiosis II, and that this chromosome would have a homologous chromosome that it separates from in meiosis I, itself having two sister chromatids. Thus, a simple doubling of the number, twice over, would have arrived at the correct final answer. Very few candidates were able to logically derive this outcome, unaware that they would need to consider that 12 was the haploid number and that they needed to work backwards carefully. Multiples or factors of 12 were observed across the answers given.

Question 5

(a) This question assessed candidates' understanding of the principles of genetic technology through their knowledge of the source of genes used in genetic engineering. Candidates were familiar with the techniques needed and often needed to fill in the precise details. Some candidates simply described one or more of the three main sources without further explanation of the retrieval process. Common errors and misconceptions included omitting that mRNA can only be extracted from a cell expressing the gene, imprecise statements that mRNA can be converted directly to cDNA, as opposed to being used as a template, or omission of the required named enzymes (reverse transcriptase and DNA polymerase) used in these stages. When considering building the DNA from nucleotides, many responses missed out on credit by simply stating that a machine was used, without reference to finding the sequence needed and where this would be retrieved from. Many did not state that the DNA is cut when referring to the use of restriction endonucleases. Many candidates wrote detailed accounts of how the gene would then be used to create recombinant plasmids, which did not answer the question. Stronger candidates included these details and were able to list the ways in which a gene that codes for a human protein can be obtained, with maximum credit being achievable.

(b) The advantages of using recombinant human insulin to treat diabetes were well understood and many candidates gained full credit. The majority of candidates recognised that insulin would be cheap to produce in large quantities, providing an unlimited supply, and that recombinant insulin would not raise any religious or ethical concerns. Many also commented that there would be little or no immune response to a human protein and that there would be no risk of disease transfer as animals were not involved. Only rarely did candidates refer to tolerance not developing or that the recombinant human insulin would act faster than its animal counterpart.

(c) Most candidates were able to explain the term recombinant DNA as the joining of DNA from two different sources, organisms or species. Alternatively, some candidates stated that DNA of the insulin gene would be introduced into a plasmid or vector. Some lost the credit by not mentioning DNA in their response or the fact that two DNA sources were required.

(d) This question proved difficult for weaker candidates, many of whom repeated some or all of their answer to **Question 5(a)**, giving detailed accounts of other techniques.

While many candidates understood the principles of how genetic engineering could be used to synthesise a gene coding for an insulin analogue, their responses frequently lacked precision. Some appreciated that gene editing would require CRISPR–Cas9 technology; in some responses, bases were altered rather than nucleotides, or segments of DNA were removed or inserted. Some named inappropriate enzymes, such as restriction endonucleases. A very few candidates mentioned that the insertion, deletion or substitution of a nucleotide would change the codon and therefore the amino acid that it coded for. Some candidates referred to the use of databases to identify the required nucleotide sequence, although some described their use to predict the three-dimensional structure of the protein analogue rather than to find its base sequence.

Question 6

(a) A very small proportion of candidates had detailed knowledge of guard cell structure. Most could only state that they have cellulose cell walls that vary in thickness. There was some confusion between guard cells and stomata with some candidates suggesting that stomata are holes in guard cells, or that guard cells are found within epidermis cells. Some candidates frequently mentioned chloroplasts, mitochondria and transport proteins, and needed to include the word 'many' in their answers to gain the credit. Few candidates then went on to identify the relative presence of grana and cristae.

(b) (i) The best answers to this question began with a simple, clear, general statement – stomata open in daylight and close in darkness. Credit was also given for two data quotes comparing the percentages open at stated times. Most candidates appropriately chose midday and midnight on a particular day, while a few correctly calculated means.

(ii) Not all candidates appreciated that the question asked them to suggest factors that can contribute to stomatal closure. For example, some stated 'temperature', rather than 'high temperature'. There was some confusion about humidity, with many answers suggesting that high humidity causes closure.

(c) This was generally a well-answered question with many candidates gaining full credit by identifying the sequence of events in the correct order. Where this was not the case, some credit was given for placing the correct letters above and below the given one (**F**), even if these were not in the right sequence.

Question 7

(a) There were many good answers to this question. Most candidates described Na^+/K^+ pumps actively transporting three sodium ions out of the axon and two potassium ions into it. They could generally state that the resting potential was around –65 or –70 mV, negative inside. Some candidates also provided more detail, for example referring to the outward diffusion of K^+ through channels, and the greater permeability of the membrane to K^+ than Na^+. Some also mentioned the presence of large anions within the axon cytoplasm.

An error that was sometimes seen was a statement that ions were moved out of or into the membrane, rather than out of or into the cell or axon. A small number of candidates described an action potential, and then stated that none of the events they had described happened. There was no credit for this. Others described the events at a synapse, again often completing their answer by stating that this did not happen.

(b) (i) This question asked candidates to describe the differences between two graphs. To be successful, a data quote and descriptions were required – for example, that the resting potential of the person with hypokalaemia is lower than that of a normal person. Many candidates gave good answers, others simply gave a series of data quotes, with no descriptive comparison. Some comparative descriptions used inappropriate terms. Time can be longer/more or shorter/less, not faster or slower.

(ii) Many candidates correctly suggested that responses to stimuli would be slower in the person with hypokalaemia. Some also explained that a larger stimulus would be needed to reach threshold potential. A common error here was to state that the threshold potential would be higher. A few candidates also worked out that there would be a lower frequency of impulses in the person with hypokalaemia.

Question 8

(a) There were many very good answers, in which several characteristic features of fungi were listed, such as being eukaryotic, heterotrophic and having chitin cell walls. Some candidates made numerous incorrect statements, for example, suggesting that fungi are prokaryotes or that they photosynthesise. There was sometimes contradiction within the answer, for example, a statement that fungi are eukaryotes followed by one that they have no nucleus. Spores were sometimes referred to as ‘pores’.

(b) There were numerous good suggestions, the most common correct ideas being that the nutrients made by the green alga by photosynthesis could be used by the fungus, and that carbon dioxide released by the fungus’s respiration could be used by the alga in photosynthesis. Some answers showed misunderstanding of the context, referring to the lichen benefiting, rather than the two partner organisms.

(c) (i) Almost all candidates knew that photosystem II is involved in the release of oxygen.

(ii) Many candidates had difficulty in explaining the curve between **A** and **B**, stating that there was no photosynthesis over this range, or that there was no light. Good answers explained that respiration took place at a greater rate than photosynthesis over this range, so that oxygen was taken in rather than released. Candidates were generally able to explain that light is no longer a limiting factor at light intensities beyond **C**, and named another factor – for example, carbon dioxide concentration or temperature – that was limiting.

Question 9

(a) Confident and correct answers to this question were quite rare. There was little evidence that many candidates had experience of using a quadrat, with descriptions that were muddled and imprecise.

Some candidates suggested a suitable size for a quadrat to be used in the field and described how it would be placed using random numbers as coordinates. Suggested sizes were not always reasonable – for example, 10 m by 10 m. Throwing a quadrat does not result in random placement, so this was not credited. Many answers described using the quadrat along a belt transect; this would not be a suitable way to assess biodiversity in a field. The incorrect spelling 'quadrant' was not accepted.

Some answers clearly described what would be counted or measured within the quadrat. However, this was often not correct or clearly stated. Answers mentioned that the number of plants within the quadrat would be counted, rather than the number of species or the number of plants of a particular species. Some correctly suggested estimating percentage cover of each species or using a scale such as Braun-Blanquet. Some missed the reference to plants in the question and described mark-release-recapture or the use of nets and pooters. Very few mentioned the use of a key to identify the plants within the quadrat.

There were many references to repeating the survey or using many quadrat placements. Answers also frequently mentioned calculating Simpson's index of diversity or calculating species density. Weaker responses often showed confusion with other formulae, such as the Lincoln index or Spearman's rank correlation.

(b) (i) There were many mistaken choices of the value of *n*. The correct value to use was 12, but 10 or 120 were frequently selected. Correct calculations from these values were able to gain some credit. Most candidates gave their answer to three decimal places.

(ii) Being able to use the calculated value of a statistical formula is important and often found to be more difficult than doing the calculation itself. Here, candidates needed to appreciate that they should ignore the negative sign with their value of r_s. If they did so, they should then have found that their value was greater than the critical value given in the table. This could then be used to conclude that the null hypothesis should be rejected, and that there is a significant, negative correlation between the two variables. Some candidates arrived correctly at this conclusion, although many of these responses did not qualify the correlation (significant or negative), or wrongly referred to a significant difference.

Question 10

(a) Many candidates recognised the mechanisms happening during and after the dive and needed to continue to provide sufficiently detailed statements, such as linking aerobic and anaerobic respiration with the presence or absence of oxygen, for the award of credit. Similarly, although candidates appreciated that anaerobic respiration would lead to lactate formation, many needed to add that it would be formed from pyruvate or that lactate would be converted back to pyruvate after the dive. There was fairly frequent mention of the oxygen debt and a good number of candidates appreciated that lactate would be metabolised by the liver. Some confused lactate with lactose or believed that the lactate could be respired under anaerobic conditions instead of glucose.

(b) Almost all candidates were able to gain credit for a suitable suggestion as to how the seal population could be conserved. Most commented on the implementation of breeding programmes or the benefits of frozen zoos in the preservation of gametes and embryos for future use. Many also mentioned the banning of seal hunting or trade in their products, as well as raising awareness and education, often linked to research on seal behaviour or their habitat. Suggestions also included the establishment of marine reserves or parks, particularly as a way of enabling captive breeding, as well as the protection of the seals' habitat. Some recognised that ocean pollution, such as oil spills or dumping of waste should be reduced, as well as fishing in or around the seals' habitat to ensure a sufficient food supply. Candidates could have mentioned reducing climate change or global warming as these were seldom seen.

BIOLOGY

Paper 9700/43
A Level Structured Questions

Key messages

Candidates should always take notice of the command word in a question. The words 'describe', 'explain' and 'suggest' all require a different approach when answering.

The number of marks allocated to a question indicates how many separate points need to be made. Candidates often made one good point and then used the remaining space to expand on the same point. This will seldom gain further credit.

General comments

Many candidates found **Question 3**, inducible enzymes, **Question 5**, recombinant DNA technology, **Question 6**, the kidneys and osmoregulation, and **Question 9**, nervous and endocrine systems, particularly challenging.

Comments on specific questions

Question 1

(a) A minority of candidates stated that the type of transport protein allowing glucose into the cell was a carrier protein or a GLUT. Many were able to name glycolysis as the process that converted glucose to pyruvate and fewer correctly named the intermembrane space.

(b) This question about the link reaction was answered quite well by many candidates. Good answers noted that pyruvate would be decarboxylated and dehydrogenated. This would lead to the production of reduced NAD and acetyl coenzyme A.

(c) This question was found to be difficult by many. Stronger candidates were able to state that less ATP would be produced by substrate-linked phosphorylation due to a reduction in the link reaction and therefore Krebs cycle.

Question 2

(a) (i) Some candidates were able to show that antibiotics act as a selection pressure and so bacteria with a resistant or mutant allele would have an advantage, reproduce and pass on that allele. Fewer managed to explain how the allele would be passed on by horizontal transfer.

(ii) Candidates found this question difficult with few scoring full credit. The mechanism of action of the drug was rarely given although some realised that the protein coded for by the resistance gene would not be produced.

(b) (i) Many were able to score quite well in the question by showing that natural selection was a result of random mating, that its effects took longer to be seen and that it did not result in a loss of hybrid vigour or a decrease in genetic diversity. For some, comparative statements were required in their answers.

(ii) A few candidates were able to state that, if new seed is not used, all the offspring would not be similar or that there would be variation and that this would not benefit the farmer.

Question 3

(a) Candidates found it difficult to express themselves clearly to explain inducible enzymes. It was expected that a good definition of an inducible enzyme would be one that is only produced, or the gene coding for its production expressed, when its substate is present.

(b) Candidates were presented with a graph showing the activity of β-galactosidase enzyme over a period of time in a medium containing an excess of lactose. They were asked to explain the shape of the curve. A small number of strong candidates mentioned that when lactose entered the bacterium it would bind to the repressor causing a shape change and that this would lead to the repressor detaching from the operator. This would unblock the promoter so that RNA polymerase could now bind and the gene would be expressed leading to the production of β-galactosidase which would then break down lactose. Most candidates were confused between repressor, operator and promoter. A majority stated that the graph levelled off due to lactose running out despite the question clearly stating that there was an excess of it. The reason for the levelling off was due to β-galactosidase active sites being fully occupied.

Question 4

(a) Many candidates realised at the start that this was about allopatric speciation and they remembered the sequence of events that led to this type of speciation.

(b) Candidates found the novel scenario of this question difficult. Many were able to state that using DNA would be more accurate and a few elaborated by stating that only a small sample would be needed or that it is quantitative. Some candidates mentioned the idea of a molecular clock while others realised that it would avoid problems relating to convergent evolution.

(c) Candidates usually gave quite vague answers about not having enough information and very few gained the credit here.

Question 5

(a) Candidates were asked to explain structural differences between cDNA and genomic DNA and why only cDNA was expressed successfully. Very few noted that cDNA does not contain introns which are non-coding sequences of DNA. It was rare to see mentioned that bacteria do not have the ability to remove introns from genomic DNA and so functional RNA is not made, hence no translation occurs.

(b) (i) Many were able to state that DNA ligase forms phosphodiester bonds; far fewer mentioned the formation of hydrogen bonds.

(ii) Most were able to state that the promoter enables the transcription of the gene and some stated that RNA polymerase binds to the promoter.

(c) For full credit, candidates needed to state that the marker gene would be added to the plasmid alongside the gene of interest and that when the marker gene was expressed a fluorescent protein would be made that would glow under UV light. This would show that the bacterium had been transformed. The most common mistake was to suggest that the marker gene itself would glow.

(d) Candidates found it difficult to compare yeast with bacteria in the production of human insulin, with the most frequent correct answer being that it was more productive.

Question 6

(a) Most candidates scored well in all three parts of this question. Urea was frequently given plus either a mention of deamination or a description of the process. As this question was based on the kidney, some thought that deamination occurred there instead of the liver.

(b) Ultrafiltration is an important learning outcome in the understanding of osmoregulation and is a sequential process that candidates struggled to explain well here. Some gained credit for correctly describing that there would be a high blood pressure in the glomerulus and then contradicted themselves by stating that molecules would diffuse through the pores in the

endothelium. There was much confusion about the role of the basement membrane and podocytes. Most seemed to know the dimensions of the molecules that would pass through the filter and those that would not.

(c) Candidates were presented with a graph showing the relationship between the concentration of urine and the mean thickness of the medulla of the kidney. They were asked to explain the relationship but many just described the relationship shown by the graph. Strong candidates noted that the collecting duct passed through the medulla and so if the medulla was thicker then more water would be absorbed.

Question 7

(a) (i) Candidates usually scored well here by identifying ribosome and DNA.

(ii) The most common incorrect answer was to state thylakoid membrane instead of thylakoid space.

(b) Most candidates scored well with a few unable to name xanthophyll.

(c) Although few named carotene as an accessory pigment, many were able to state that it absorbs wavelengths of light not absorbed by chlorophyll a, then passes on the light energy to the reaction centre. Some lost credit by omitting the word energy. Few mentioned that this extended the range of wavelengths absorbed by the plant and so improved the efficiency of the light-dependent stage of photosynthesis.

Question 8

(a) Candidates found this question on CITES quite difficult. CITES is different from IUCN and some found it hard to distinguish. Candidates should know that CITES prevents illegal trade in species and that any trade requires a permit. Some were able to state that it promotes awareness or education.

(b) This straightforward recall question on the features of the kingdom Animalia resulted in a range of answers from excellent to very poor.

Question 9

(a) Candidates were required to compare the nervous system with the endocrine system. This question set the learning outcome in a novel context and most candidates found this quite challenging, leading to muddled or repetitive answers. A few candidates noted that sense organs would be required to detect prey and that they would need to send impulses quickly to the CNS or brain for processing. Some added that the response would be fast and it would be carried out by muscles.

(b) Most were able to correctly identify the myelin sheath and the axon surface membrane or dendrite. Fewer successfully identified the cell body as a part of the neurone that contains mitochondria.

(c) (i) The main problem that candidates had with this question was that the *y*-axis for the width of the sarcomere was from 5 up to 0. Consequently, many stated that the sarcomere was increasing in width instead of decreasing. Despite this, some were able to obtain credit by referencing cross bridge formation and power stroke.

(ii) Very few candidates showed detailed comprehension about the role of calcium ions in muscle cells, particularly the role of the sarcoplasmic reticulum. Some mixed up the role of calcium ions in the pre-synaptic knob with that in the muscle cell.

Question 10

(a) Many candidates were able to describe an ecosystem as a self-contained unit where a community of organisms interacted with both biotic and abiotic environments. There were many correct references to food webs and recycling.

(b) (i) The most common correct answer to this question on the mark-release-recapture method was that the population must remain stable. Few mentioned that the animals must be mobile and that time

must be allowed for the marked animals to mix with the rest of the population. Some candidates found this question difficult.

(ii) Most candidates correctly calculated that the estimate of population size of the frogs would be 69. Answers to mark-release-recapture questions must always be whole numbers as a population cannot have a fraction of an animal. Some candidates lost credit because of this.

BIOLOGY

Paper 9700/44
A Level Structured Questions

Key messages

Candidates had the most difficulty interpreting the graphical questions and were sometimes imprecise when quoting figures. Candidates should take care when quoting data and ensure that they select the appropriate number of significant figures and include units.

Candidates should make sure when setting out their response to a describe and explain question that the describe comment is linked to the explain comment.

General comments

Overall, candidate responses were of a very high standard, with many achieving high levels of credit.

Question 5 was found to be the most difficult on the paper. A common misconception was regarding gene regulation in prokaryotes and in eukaryotes. In prokaryotes, operons and an operator are present, with the repressor protein binding to the operator and blocking the RNA polymerase from binding to the promoter. For gene regulation in eukaryotes, there are no operons or operator, and transcription factors bind to the DNA, often at the promoter to determine if RNA polymerase can bind to the promoter.

Question 6 highlighted the need for precise terminology and the use of key words.

Comments on specific questions

Question 1

(a) The mechanism of ADH release in response to a decrease in blood water potential was well understood. Most candidates began by stating that low water potential in the blood would be detected by the osmoreceptors in the hypothalamus, which would bring about an increase in the release of ADH from the posterior pituitary gland. Some referred to the osmoreceptors shrinking and stimulating the neurosecretion of ADH. Credit was not awarded for descriptions of ADH being synthesised by the posterior pituitary gland, rather than the hypothalamus, or being excreted, rather than released. References to osmoregulators were not credited.

(b) (i) The vast majority of candidates understood that molecules such as cAMP act as second messengers in cell signalling, although some suggested that they constituted the enzyme cascade.

(ii) Many candidates appreciated that stimulation by kinase enzyme would cause vesicles containing aquaporins to fuse with the cell surface, or luminal membrane, thereby increasing the membrane's permeability to water. A significant number of responses referred to the cell membrane, rather than the cell surface membrane or did not mention the effect of the aquaporins on permeability, simply stating that more water would enter the collecting duct cell. This fusion of vesicles is not an example of exocytosis, the answer given by a minority of candidates. Candidates should note that it is the membrane that becomes more permeable to water, not that the water increases in permeability.

(iii) Most candidates correctly showed the direction of movement of water in the collecting duct following ADH stimulation, either by drawing one long arrow or a succession of smaller ones from the lumen of the collecting duct, through the epithelial cell and into the capillary. Common errors were for arrows to enter the collecting duct cell from the lumen and go no further or for the arrow to go from the cell into the capillary but no arrow from the lumen to the cell. Very occasionally, arrows were drawn from the cell into the lumen.

(c) Most candidates were able to suggest effects of the kidney disorder on osmoregulation, often beginning their response by stating that less or no water would be reabsorbed so the water potential of the blood would remain low. Many also recognised that there would be a larger volume of urine produced or that it would be more dilute. The symptoms experienced by patients with this disease were also frequently described, such as thirst, dehydration or fatigue.

Rather than focusing on the osmoregulation aspect, some candidates wrote accounts of how the inability to respond to ADH stimulation would prevent the enzyme cascade, resulting in fewer vesicles containing aquaporins fusing with the cell surface membrane and therefore a decrease in its permeability to water. Vague references to the amount of urine or frequency of urination were not credited. Candidates should focus on using precise quantity terms for urine production, for example, volume or concentration. When describing water potential in questions such as this, candidates should note that it is the water potential of the blood they should be referring to.

Question 2

(a) The relationship between genes, proteins and phenotypes as illustrated by Huntington's disease was, in general, well answered. Many candidates appreciated that a mutation in the HTT or huntingtin gene would lead to the synthesis of non-functional huntingtin protein which would then have a profound effect on the phenotype. There were many references to uncontrolled or involuntary movement, often expressed as an inability to walk or talk; fewer mentioned cognitive or behavioural changes. Many candidates also recognised that the mutation resulted in a dominant allele with many CAG repeats. Weaker answers missed naming the gene or its protein, or stated that neurological degeneration would occur without any further detail.

(b) The inheritance of retinitis pigmentosa was correctly described by many candidates. Most recognised that only males, and no females, would have the disease and went on to link this with the inheritance of the Y chromosome. Some candidates could have made it clearer that only males have the Y chromosome, or conversely, females have only X chromosomes. Many candidates understood that all male children of a father with retinitis pigmentosa would also have the condition or vice versa.

(c) The genetic cross of a healthy male with a heterozygous female with incontinentia pigmenti was correctly carried out by most candidates. Credit was lost most commonly for not identifying the sex of the offspring, resulting in the wrong ratio. Some candidates gave the father's genotype as $\mathbf{X^aX^a}$, rather than $\mathbf{X^aY}$ or confused the healthy recessive allele with the dominant abnormal one. Gametes or parental genotypes were occasionally omitted. Candidates should note that the offspring phenotype in a sex-linked cross must state both the phenotype of sex and the phenotype due to the genotype.

(d) This question was more challenging and many candidates found the consequences of a mutation in a regulatory gene difficult to explain. While many appreciated that the mutation would lead to a non-functional repressor protein, they negated the credit by stating that it could no longer bind to the promoter, rather than the operator. Candidates frequently commented that a lack of repressor protein could lead to overexpression of genes and needed to add that these genes would be structural. Candidates gained credit for showing understanding that, in the absence of a repressor, the structural proteins would continue to be synthesised leading to errors in metabolism or disease. Few candidates suggested that the abnormal repressor would continue to bind to the operon so that there would be no transcription of the structural genes and therefore no protein produced. Candidates should note that they must be clear to indicate whether the gene is regulatory or structural when both are relevant in the response.

Question 3

(a) (i) The majority of candidates were able to apply the Hardy-Weinberg equations. The strongest candidates clearly showed all their working as instructed to achieve full credit. Weaker candidates found this question particularly challenging, often missing out on credit by omitting working.

Some candidates showed some working but needed to give the answer as a number, for example, $q = \sqrt{0.068}$ and not $q^2 = 0.068$. There were many who rounded their answers too early so did not achieve all of the available credit. Candidates should note that they should only round for the final answer. There were some instances of using h and H in the working instead of *q* and *p*, or mixing up *p* and *q*. Occasionally, no *p* and *q* letters were given in the working, resulting in no credit awarded for working.

(ii) Most candidates could state two reasons why the domestic cat population does not meet the conditions needed to apply the Hardy-Weinberg principle. The most common responses were no random mating and the presence of selection.

(b) This 'suggest' question about why cats with the tailless phenotype became common in the small cat population on an island was well answered, with many gaining full credit. Weaker answers needed to refer to alleles and cited increased frequency of tailless cats. Some also mentioned inbreeding depression which may or may not be taking place in the population and is not relevant in this example.

(c) Candidates clearly understood the process of natural selection to describe how the spotted allele increased in frequency in the cheetah. Many focused on how the AO2 context fitted the main steps of the natural selection process. A few candidates missed out on credit by referring to genes rather than alleles and others were too vague and referred to alleles being passed on, not highlighting that it would be the spotted allele that would be passed on in this example. Many struggled to express the selective advantage correctly, they did not always identify the selection pressure particularly well, or that individuals with spots would have the selective advantage. Some candidates incorrectly wrote that the allele has the selective advantage. There were many vague descriptions of getting more food or spotted alleles surviving rather than the phenotype of being spotted enabling survival or reproduction.

Question 4

(a) Most candidates were able to correctly complete the table with the main features for the named kingdoms. There was some confusion amongst responses suggesting that Fungi do not have unicellular species and that Protoctista do not show autotrophic nutrition.

(b) This question had a variety of responses. The most common error was omitting to state whether it was meiosis I or II. It was clear that many candidates needed to recognise the stages from the diagrams.

(c) Candidates were asked to name the two prokaryotic domains and describe the differences between them. Some candidates were clearly familiar with this part of the syllabus and were able to name Bacteria and Archaea. Some incorrect spellings of Archaea were seen. The question was generally well answered with the most popular response being about peptidoglycan cell walls and often candidates knew about the difference in having DNA associated proteins. Some candidates were confused about the second prokaryote domain, with eukaryote or fungi sometimes given, and virus was also seen. Candidates should take care to not separately list descriptions of features of one kingdom followed by a separate paragraph of descriptions for the other kingdom without clearly taking one feature and describing its difference. A table is a very suitable way of setting out this type of response.

(d) Most candidates successfully classified viruses by nucleic acid type and number of strands.

Question 5

(a) Many candidates were able to achieve a high score on this question about PCR. The temperatures stated for each stage of the process were almost always correct and the appropriate term for the stage was commonly used. Responses frequently elaborated on each stage, with many candidates knowing that hydrogen bonds are broken to separate the DNA stands, that primers attach to DNA and the majority knew that Taq polymerase is required to build the new strands.

One common error was to not state that the hydrogen bonds are broken in denaturation or that the strands are separated. The main confusion was in the extension stage and the role of Taq polymerase. Some incorrectly called it an RNA polymerase, and many gave vague descriptions of making DNA or making phosphodiester bonds.

(b) (i) The novel context of this genetic engineering question was found to be difficult. The *tTav* gene had to be constructed first, instead of the more familiar method of obtaining the gene. Candidates were generally secure in their knowledge of how to obtain the components of the *tTav* gene and could quite often give more than one method to do so. However, rather that stating that the DNA was being obtained from the bacteria or virus they often stated that it was the entire gene that was being obtained so narrowly missed achieving the credit for this idea.

It was clear that the majority of candidates knew the role of DNA ligase in joining two sequences of DNA together but they often missed out on the credit as they suggested that a plasmid was the vector and that ligase was being used to join the gene and the plasmid rather that the DNA obtained from the virus and the bacteria. With the context of adding the gene to an egg – a eukaryotic cell – it meant that a plasmid would not be an appropriate vector to choose. When stating the correct vector (or use of a vector in general) candidates usually knew that the gene or recombinant DNA needed to be inserted into it. It was quite common for answers to suggest that the viral vector is injected into the egg rather than infecting the egg; few referred to injection of the gene into the egg. A minority of responses finished with an explanation of the *tTav* gene being incorporated into the genome of the egg.

(ii) Most candidates needed to take note of the cell being eukaryotic so, a significant number of responses suggested that the tTav protein behaved as a repressor protein. Some were able to give the correct explanation of transcription being prevented either by preventing the binding of RNA polymerase or the transcription factor to the promoter.

(iii) Candidates often repeated information provided in the question about tetracycline stopping the action of the protein and needed to explain the significance of this in enabling the larvae to survive and develop into adults. Many suggested that the role of tetracycline was to check that the tTav gene had been successfully transferred so did not achieve the credit.

Question 6

(a) The vast majority of candidates had clearly learnt the AO1 definition of an ecosystem in detail and achieved full credit in one sentence. Some were confused by the idea of living and non-living factors and referred to living and non-living organisms in their definition.

(b) Many candidates achieved credit for their description of the biological species concept. A significant few missed out as they omitted the act of breeding and stated that organisms could simply ‘produce’ fertile offspring. Some candidates were confused with the morphological and ecological species concepts.

(c) Although some candidates described sympatric speciation and gave extensive reasoning for the emergence of different species in this way, the majority used the information provided in the diagram to explain that a geographical barrier existed to prevent gene flow and that this was the process of allopatric speciation. Many also elaborated with descriptions of different environments or selection pressures. A few did not gain credit as they used terms such as geometric or geological separation.

Question 7

(a) (i) Most candidates were able to state that the deoxygenated line increased before levelling off at 48 hours. The strongest candidates described the increase as being gradual up to 24 hours with a more rapid increase after this point. A significant minority of candidates confused the oxygenated and deoxygenated lines on the graph and so described the wrong line. Many candidates struggled to read accurately from the graph and give a correct data quote and also described the deoxygenated plot at 0 hours and the oxygenated line as being 'at zero percentage' when they were clearly above the line of the *x*-axis.

(ii) Many candidates could not describe the structure of aerenchyma accurately with most simply stating 'air space/s', as if aerenchyma was the name for the air spaces themselves rather than a specialised tissue that contains many or large air spaces. Most candidates were able to go on to describe how aerenchyma aids the diffusion of oxygen for aerobic respiration for credit. Common errors seen were to simply state 'for respiration' without clarifying aerobic, to describe the diffusion of 'gases' or 'air' without specifying oxygen, and to omit the destination of the oxygen despite the question indicating it is an adaptation that allows the roots to be submerged.

(b) Many candidates could describe an increased tolerance to ethanol and stated that anaerobic respiration was taking place. A significant number needed to make it clear that it is just the root cells and not the plants themselves that have a higher tolerance to ethanol. Similarly, many candidates knew that more ethanol dehydrogenase was present to break down the ethanol accumulating via anaerobic respiration and needed to state that more of these enzymes are present in rice plant root cells to be credited. Candidates often had the idea that plants grew taller and a few of these could describe the faster stem or internode growth that makes this possible. Many scored credit by explaining that being taller allowed leaves to be above the water level for photosynthesis or gas exchange.

Question 8

(a) The strongest candidates were able to accurately label all three regions of the striated muscle. Region **R** was the most common correct answer with many candidates being able to recognise that the very darkest bands would contain both actin and myosin. Some candidates labelled areas that were not within the sarcomeres. The main error was to mix up the I-band where label line **P** should point with the H-zone, where label line **Q** should point. Candidates may benefit from practise in interpreting photomicrograph images of muscle tissue.

(b) Most candidates were able to demonstrate a secure understanding of the roles of troponin and tropomyosin in the sliding filament model, securing the majority of the credit available. The most common error was to state that myosin (alone) binds to actin rather than the myosin head.

(c) The majority of candidates gained credit by suggesting that ATP would be lacking or used up or not enough. Stronger responses also gave the presence of lactate from anaerobic respiration as the cause of muscle fatigue and then some could also link this to a lack of oxygen, often describing 'oxygen debt' in their answers. Other answers seen were a lack of calcium ions and glucose. Weaker responses described the muscle fibres themselves as becoming fatigued simply from contracting too many times.

Question 9

(a) There was an error in Fig.9.1 for **Question 9(a)** where reduced NADP was incorrectly stated as reduced NAPD. This has been corrected in the published version of the paper. Due to this error, full marks have been awarded to all candidates for this question to make sure that no candidates were disadvantaged.

(b) This question was generally well answered. Most candidates correctly interpreted the graph, and a few were able to explain why the rate of photosynthesis increases with increasing light intensity. Candidates should note that when asked to describe and explain a graph that has different sections, it is best practice to first describe one section and then explain it before proceeding to the next section. In this case, describe the increase then explain the increase, then next describe the plateau then explain the plateau. This would make responses clearer and more likely to achieve credit. Candidates should also be careful with descriptions of a plateau. It is not equivalent to say that there is no further increase – it could be possible that it decreases and the description must make it clear that it stays constant.

Question 10

(a) (i) Many candidates were able to define the term respiratory quotient as the volume, moles or molecules of carbon dioxide produced divided by the volume, moles or molecules of oxygen taken in. Some did not gain credit as they needed to mention the volume, molecules or moles of each gas, and others by stated that oxygen would be produced rather than consumed.

(ii) The calculation of the number of molecules of oxygen used when one molecule of linoleic acid is respired aerobically was correctly performed by the majority of candidates to achieve the answer of 25.

(iii) Most candidates were then able to calculate the respiratory quotient for linoleic acid, 0.72, using their figure from **Question 10 (a)(ii)**.

(b) The interpretation of the graph of the change in respiratory quotient over a period of fasting proved difficult for many candidates of all abilities. Although many provided a suitable data quote, figures were sometimes misread, needed to include the initial reading at 40 minutes or were not given to the correct decimal place. Some candidates appreciated that the RQ of 1.0 signified that glucose, or carbohydrate, was being used as a respiratory substrate and that it decreased because glucose was being used up. Very few commented on the respiration of both carbohydrate and lipid as the RQ decreased, or they suggested that the metabolism of protein would account for the decrease.

Once the RQ became constant at 0.7, many candidates stated that lipid would be the main respiratory substrate. Occasionally, credit was not given for simply stating that carbohydrate or lipid would be used without any further qualification, or candidates tried to explain the results in terms of oxygen uptake and carbon dioxide production. Some believed that a low RQ would indicate anaerobic respiration in the hummingbird. Candidates often wrote a description of the graph and all its sections first, then a second paragraph that suggested the explanations for the results without directly linking back to the initial descriptions. Candidates should set out their response to a describe and explain question with linked statements between the description and its explanation.

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Planning, Analysis and Evaluation

Key messages

Careful reading of each question before starting to write is necessary to ensure that the question is answered as asked and that irrelevant information is not included in the response.

When planning an investigation, it is important to set out the work in a logical way and avoid repeating details that are provided.

Candidates should be given opportunities to analyse a variety of statistical data; past exam questions are a useful resource.

General comments

In **Question 1(b)(i)**, those candidates who had practised planning investigations and this type of question were more likely to be able to address all the key aspects of the method. To make best use of exam time, details already given in the question, in this case on page 2, should not be repeated as no credit is available for this. When drawing graphs, as in **Question 1(b)(ii)**, the use of a sharp pencil is important so that smooth clear lines can be drawn.

For questions such as **Question 2(a)(iii)**, it is important that candidates understand the difference between the control for an investigation and variables that need to be standardised. Terminology is important when referencing standard error. Where there is overlap between standard error bars, this should be described, in this case, as no significant difference between the insect attraction rate of the models. The term 'insignificant' should not be used when discussing statistical data. Candidates would benefit from opportunities to practise writing null hypotheses, for example, whenever a suitable experiment is carried out.

Comments on specific questions

Question 1

(a) (i) Candidates were asked to outline how a colorimeter should be prepared so that correct measurements of absorbance can be obtained. Several candidates gained credit by stating that the colorimeter should be calibrated. The best answers included details about the use of distilled water and setting the colorimeter to zero. Comments about cleaning the colorimeter did not gain credit.

(ii) Most candidates were able to use **Fig. 1.2** to correctly calculate the rate of change in absorbance at pH 2.0 as 0.0036 au s^{-1}. Answers given to more significant figures or with a negative sign also gained credit. A few candidates lost credit by only calculating the change in absorbance or attempting to calculate a percentage change.

(b) (i) This question was often well answered, and many candidates were able to describe a suitable method to investigate the effect of pH on the rate of protein hydrolysis by pepsin.

Most candidates suggested a range of pH values to test; to gain credit at least five pH values should be stated and none of these should be greater than pH 6.5. Many candidates considered the variables that would need to be controlled in this investigation. The volume of pepsin chosen should be small enough to fit into the colorimeter tube; volumes greater than 3 cm^3 were not accepted.

Many candidates gained credit by controlling the temperature of the solutions using a water-bath. Candidates are always asked to give a method that is 'set out in a logical order' and is 'detailed enough to allow another person to follow it'. The best responses included details of how to equilibrate the solutions before taking measurements; the enzyme pepsin should always be equilibrated in a separate test tube from the substrate. Several candidates only equilibrated the pH albumen solution and were therefore unable to gain credit. The term 'acclimatise' is not appropriate in this context. A few candidates mixed the pepsin and pH albumen solutions by stirring or swirling.

The idea of measuring absorbance over time was almost always conveyed; credit was given to those candidates who noted the information given on page 2 and measured the absorbance at set time intervals. Most candidates recognised the need for replicates in the investigation, and a few linked these to the calculation of a mean rate of protein hydrolysis. The question also asked candidates for a method to determine the optimum pH of pepsin. Several candidates were able to state that the optimum pH was the pH with the maximum rate of protein hydrolysis. A small number of candidates explained that measurements should be taken for a narrower range of pH values around the pH with the maximum rate. The majority of responses incorporated some form of risk assessment. For example, pepsin might cause irritation and gloves should be worn. Simply stating the level of risk was not sufficient.

(ii) Candidates were asked to complete the sketch graph to predict the effect of pH on the rate of protein hydrolysis by pepsin. Many responses included a correctly labelled *y*-axis: rate of change in absorbance or rate of protein hydrolysis were both acceptable. Most candidates drew a traditional pH curve, with a clear peak. Some candidates lost credit because their line did not show a zero rate at pH 6.5.

(c) (i) A few conclusions could be made from the results of the protein electrophoresis shown in **Fig. 1.5**. Several candidates were able to conclude that test condition 2 decreases the quantity of CA3 and Sep70 because pepsin can hydrolyse the proteins. Very few candidates were able to fully interpret the different test conditions to conclude that acidic conditions do not change CA3 and Sep70 if pepsin is not active. This could be determined by looking at the results for test conditions 4 and 6.

Candidates were often familiar with gel electrophoresis and recognised that the distance travelled by the proteins was linked to their size. The use of a comparative statement when discussing the results was necessary to gain credit. Only a few candidates made incorrect references to DNA.

(ii) The strongest responses refined the student's conclusion, stating that pepsin only causes damage if acidic conditions are also present. A few high scoring candidates appreciated that the reduction in quantity of CA3 and Sep70 may not actually cause damage to the laryngeal epithelium. Some candidates gained credit for the weaker statement that 'correlation does not mean causation'.

More candidates focused on issues with methodology, such as the small sample size or the lack of a statistical test, rather than why the results did not support the conclusion. Several candidates gained credit by stating that no replicates had been obtained. Strong responses noted that the mammalian laryngeal epithelium probably did not come from a human. Noticing that the investigation was carried out in a laboratory (in vitro) was also creditworthy.

Question 2

(a) (i) Most candidates correctly identified the independent variable as the number of insect attraction events in six hours. A few candidates lost credit by omitting number or rate in their answers.

(ii) Candidates were asked to state two variables that the biologists should standardise when making models for the investigation. Therefore, responses that considered other aspects of the investigation were ignored. The size and shape of the models were often correctly identified. The materials used, the yellow colour and the brightness of the models could also be standardised. References to standardising the pattern or number of spots did not gain credit; the question stated that the pattern had already been standardised, and any change to the number of spots would also change the pattern of spots.

(iii) Several candidates recognised that a suitable control method would involve the web and no spider model. Glass beads, colourless models or dead spiders would not be suitable to use in this investigation.

(b) (i) Candidates were asked to discuss the conclusions that can be made about the effect of colour and pattern of spots on the models on insect attraction rates. Many candidates gained credit by stating that models with yellow colour have high insect attraction rates. References to brighter or lighter colours being more attractive to insects were not creditworthy unless the colour yellow was also stated. Further credit was then given for a suitable data quote from **Fig. 2.2**. Several candidates lost credit by not giving units, or by giving an incorrect value, such as 0.7 number of insects h^{-1} for model **E** as opposed to the correct value of 0.07 number of insects h^{-1}.

Candidates often noticed the overlap of standard error bars for the yellow models **A**, **C** and **D**. The strongest responses stated that this overlap indicated that there was no significant difference between the insect attraction rate of these models. The best responses clearly stated which models had error bars that overlapped or did not overlap and then linked this to whether there was or was not a significant difference. References to the size of the standard error and to reliability did not gain credit.

Candidates were asked to discuss the conclusions that can be made about the effect of colour and pattern of spots on the models on insect attraction rates. Strong responses therefore made a clear statement linking both colour and pattern to insect attraction rates. For example, stating that yellow colour increases insect attraction rates, but pattern has little effect.

(ii) Candidates were sometimes able to give the correct null hypothesis, stating that there is no difference between the mean insect attraction rates of the models. A common error was to state that there is no difference between insect attraction rates and the models, when these are two very different variables. Some candidates incorrectly stated that there was no correlation rather than no difference or did not specifically refer to the models in their answer.

(iii) Candidates were asked to give two reasons why the *t*-test would be suitable for analysing the data shown in **Fig. 2.2**. Many responses correctly noted that the data is continuous and normally distributed. The idea that a *t*-test could be used to compare the means of two different models was stated by several candidates. It is important that candidates apply their knowledge of statistics to the investigation being considered; no credit was given for stating that the standard deviations are approximately the same as **Fig. 2.2** shows that this statement is not true.

(c) Many candidates were able to make some suggestions about how the investigation could be improved. The strongest responses came from candidates who had read and noted all the information given about golden orb weaver spiders on page 9 and then gave precise answers. These responses suggested that the investigation should be carried out in Southeast Asia and Australia, or that measurements should be taken during the day and the night. Vague references to different locations or measuring for a longer time were not sufficient to gain credit.

Several candidates suggested correctly that the scientists could use more models with a greater variety of colours and patterns. Finding the insect attraction rate of a living golden orb weaver spider on the web would also be valid. A few candidates noted that the scientists could choose to count only the insects that touch the model or the web; those insects that flew towards the web might not be eaten by the spider. References to using different species of spiders or carrying out the investigation in a laboratory did not achieve credit as these would be different investigations.

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Planning, Analysis and Evaluation

Key messages

Use of key scientific terminology to describe and explain biological processes and the use of equipment is essential.

An outline plan is useful to produce a clear logical method for an investigation, ensuring the correct sequence of steps without including unnecessary information.

Clear steps to show working for calculation questions is important.

Quoting data from graphs should be as precise as possible but without stating figures with an impractical number of decimal places.

Information in the question stem is provided to guide candidates to the specific aspect of biology being tested. Candidates should read questions very carefully to establish the focus of each question and avoid including irrelevant material.

General comments

Candidates should be aware that where the question asks for a certain number of responses, such as in **Question 1(a)** and **Question 2(a)**, where two variables were required, the list rule is applicable, and any incorrect answer could reduce the credit awarded.

Candidates should take care to use the term equilibration when using a water-bath to bring solutions to a desired temperature, rather than 'acclimatisation' which is incorrect.

For **Question 1(d)**, some candidates would have benefitted from greater experience and knowledge of how a colorimeter works and that the values generated will be absorbance or transmission values.

Question 2(c)(i) showed the importance of understanding command words, in this case understanding the meaning of 'evaluate' was required to achieve full credit.

Question 1

(a) Many candidates gave clear responses demonstrating an understanding of the importance of the mass and the age of the seedlings. Fewer answers mentioned the time spent grinding the seedlings and the time in the centrifuge that would also affect the final concentration of the enzyme.

(b) (i) The strongest candidates recognised the error related to temperature and that the solutions would not be at 30 °C when mixed. These candidates used the information provided and demonstrated an understanding of equilibration and were able to provide a clear modification. The term 'acclimatisation' was not accepted as an alternative to equilibration. The modification required each of the solutions to be equilibrated separately before mixing. A common mistake was to equilibrate the buffered PPP and then add the extract. It was not clear that the extract had been equilibrated. Common misconceptions related to 30 °C not being the optimum or the use of faulty water-baths.

(ii) Many candidates recognised that the enzyme would be denatured and used the correct scientific term in their response. Weaker responses included long explanations with references to neutralisation and the pH being no longer optimum.

(c) Many strong candidates produced clear, fully labelled tables showing correct volumes of phenolphthalein and distilled water used for each dilution. Using a table with detailed headings including units and the use of distilled water is a reliable way to present this information.

Common errors in tables included using mixed units for concentration – mmol / dm^3 and per cent, a lack of any headings and listing dilutions greater than 2%.

Some candidates confused proportional dilution with serial dilution.

(d) The question asked how the dilutions and a colorimeter might be used to identify the concentration of the reaction mixture; it was not a general question about the use of a colorimeter. Most candidates showed knowledge of the data provided by a colorimeter, providing answers in terms of colorimeter values or the intensity of pink colour. Very few candidates included reference to the use of a calibration curve. The weakest candidates used indicator strips to see the range of colour intensity.

(e) The strongest candidates used the relevant information provided, demonstrated a sound understanding of the specific aim of this method and how to determine the optimum pH in terms of absorbance. Few mentioned the possibility of repeating with narrower intervals around the optimum pH identified.

Most candidates mixed the enzyme, PPP and buffer solutions; fewer equilibrated the solutions before mixing. Examples of errors within the method included the use of a range of phenolphthalein concentrations rather than a range of pH buffers, a range of pH values above pH 7, confusing phenolphthalein with PPP, and not using a buffer or enzyme. Few responses included a method to identify the optimum pH.

Most candidates gave a basic risk assessment in terms of the enzyme or PPP. However, a risk assessment for the pH buffers required more detail as not all pH values would be corrosive. Water at 30 °C is not a risk.

(f) (i) Most candidates were able to identify the anomalous data plot. Most candidates described the anomaly as not fitting the trend rather than providing an explanation in terms of the anomaly being higher than the V_{max}. Many candidates cited human error as the explanation.

(ii) Many candidates gained credit by reading off the data from the graph with precision and providing the correct units, as requested in the question stem. A large number of candidates omitted to include the units. Weaker candidates gave data from the *y*-axis instead of the *x*-axis. Data from the *x*-axis was often inaccurate.

(iii) Most candidates who read the graph with precision in **Question 1(f)(ii)** gained full credit by calculating the percentage increase correctly. Weaker candidates did not know how to use the figures from **Question 1(f)(ii)** to calculate a percentage increase.

Question 2

(a) Strong candidates demonstrated an understanding of which variables it is possible to control in an ecological study. Weaker responses indicated a lack of understanding about sponges and what variables might affect their diversity, referring to sampling at the same time of day or using the same camera.

(b) Most candidates presented clear working and rounded their answer to the nearest whole number, as requested in the stem of the question. Weaker candidates misread the scale on the graph or did not understand how to enter the data into the formula for beta diversity.

(c) (i) This question challenged candidates to review and evaluate all the information provided to either support or not support the stated conclusion. Many candidates identified which stations had the least human activity and quoted appropriate data to support the conclusion. Fewer candidates

recognised the need to provide evidence that did not support the conclusion. Candidates should make it clear whether the evidence given supports or does not support the conclusion.

(ii) The strongest candidates were able to interpret the question correctly and gave two different conclusions supported by evidence and grouped the sampling stations appropriately. Weaker candidates did not distinguish between this question and **Question 2(c)(i)**. Some candidates repeated previous answers, wrote in terms of the beta diversity index rather than the species diversity, or simply produced a list of data quotes not linked to a conclusion.

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Key messages

Careful reading of each question before starting to write is important when structuring a response.

When planning an investigation, candidates should focus on what the investigation is trying to test, how to measure the effect and how to standardise other variables.

Candidates should look at past examination papers to ensure they know the correct terminology and understand how to answer commonly recurring questions.

General comments

In questions such as **Question 1(a)(ii)**, where candidates were asked to plan a breeding experiment, it is important to consider if the temperature should be kept constant and if so, to ensure it is carried out in an appropriate way. Most candidates merely stated that the room should be kept warm or that a water-bath should be used for this. However, an incubator would be more appropriate for this experiment than a water-bath.

When analysing data using the chi-squared test, candidates should be aware that the column of critical values for $p = 0.05$ is the one that should always be used and that the p-value and critical χ^2 value are not interchangeable ideas.

In **Question 2**, candidates were asked about control experiments. Candidates needed to be aware that controls are always needed for a comparison, which should be stated, and that the focus needs to be on what is being compared.

Candidates need to carefully consider the information presented in graphs, as in **Question 2(c)(i)**, where they needed to appreciate what 'most effective' would look like.

Significant figures will usually feature in calculation questions and candidates should be fully versed in their use and highlight where the question states a specific requirement.

Comments on specific questions

Question 1

(a) (i) Most candidates were able to identify a suitable hazard of the investigation, its associated risk and the precaution the student should take. Strong candidates were specific with their language and ensured all three components matched each other. Many candidates correctly focused on the nature of the anaesthetic. Some responses were not credited as they cited the risk to the fruit fly and not the student.

(ii) A few candidates gained full credit for this question. Most did not give enough detail in terms of which flies were being put together in the specimen tubes for the first cross; phenotype and sex were needed. Most candidates correctly mentioned the removal of the adult fruit flies from the specimen tubes before the offspring developed. Many answers were vague about how to carry out the second cross and merely stated that the procedure needed to be repeated. Some candidates realised that a certain dose of the anaesthetic would be required to anaesthetise the fruit flies but not to kill them.

This investigation was aimed towards the analysis of the F2 phenotypic ratio which required candidates to count the number of individuals with each type of phenotype. Additionally, a large number of offspring should be produced and counted to reduce the effect of chance on the F2 phenotypic ratio. Simply stating that the investigation should be repeated was not sufficient. Few candidates realised the small size of the fruit flies and the need to use a magnifying glass or microscope to view them to determine their phenotype. Very few realised the risk of double counting the flies and stated a method to avoid this. For example, the flies could be removed to a different tube once they have been counted.

(iii) Most candidates correctly stated the ratio of offspring to be 9:3:3:1 and matched it to their phenotypes. Many supported their answer with the genetic cross but some who realised the nature of the cross merely gave the ratio and phenotypes.

(b) Most candidates were able to correctly identify the suitable critical value from **Table 1.2** and compare it to the calculated value of chi-squared (χ^2). The strongest responses stated that the calculated value of χ^2 was less than the critical value and therefore accepted the null hypothesis. Some candidates got this the wrong way around.

Question 2

(a) Many candidates identified the type of treatment as the correct independent variable. Some candidates chose to name all the treatments which was also correct. Those who chose this method and omitted one or two treatments scored no credit.

(b) Most candidates correctly identified two other variables that needed to be standardised in this investigation with many focusing on the volume and concentration of the EchAMP. The most common error in this question was stating the word 'amount' in the place of volume. Generally, using the word 'amount' in a biology exam is not precise enough to gain credit.

(c) (i) Many candidates struggled with the concept of a negative control and how to word their response appropriately. The best responses stated that the control was required to compare the effect of no EchAMP on bacterial growth.

(ii) More candidates correctly stated that this positive control was needed to compare the effect of EchAMP to that of bacitracin.

(d) (i) Most candidates successfully labelled the axes, plotted the missing points and completed the key correctly. Some candidates omitted the labels for the axes or the units for time. Some candidates had plotted the points at 8 hours instead of at 7 hours.

(ii) Many candidates were able to correctly compare the effect of both EchAMP and bacitracin on the growth of *E. coli* over the course of 7 hours. The best responses stated how bacitracin reduces population growth of *E. coli* more than EchAMP over the course of 7 hours. They also noticed the lack of difference in their effect during the first 6 hours. Some candidates incorrectly thought a more positive gradient signified a greater effect.

(e) (i) Most candidates correctly stated the null hypothesis for the *t*-test. Good responses made use of the text that preceded the question to formulate their hypotheses. Candidates should ensure they utilise the common structure for these types of questions to ensure credit. Some candidates attempted their own style of null hypothesis with limited success.

(ii) The majority of candidates correctly input the data into the formula and derived the correct answer to four significant figures, 9.370. Candidates made errors in either the number they used for the sample size (9), manipulation of the formula or in too many significant figures in their answer.

(iii) Most candidates suggested reasons why the stated conclusion might not be valid. Good responses highlighted how EchAMP was not tested on people, was only tested on *E. coli*, may affect beneficial bacteria and was a lot less effective than bacitracin. Excellent responses noted the protein nature of EchAMP and how it might be broken down in the digestive system due to the presence of proteases. Fewer candidates noted that EchAmp did not kill all the *E. coli*, so was not fully effective, and may cause side effects in humans.

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Key messages

Careful reading of each question before starting to write is important.

When planning an investigation, it is important to make sure that all parts of the investigation are addressed and information that has already been provided is not repeated.

Candidates should be given opportunities to analyse a variety of statistical data.

General comments

Question 1

Candidates should be clear about the difference between the dependent and independent variables in investigations. Experience in carrying out practical work is very important in candidates' preparation for the exam. Candidates were often able to demonstrate a good ability to analyse statistical data. When describing how to make a serial dilution, clear diagrams of the serial dilution with full annotations are helpful.

Question 2

Careful reading is needed in questions such as **Question 2(b)(iii)**, where candidates were asked about processing of results rather than how the method could be improved.

Comments on specific questions

Question 1

(a) (i) Several candidates correctly identified that 0.264 g of ABA should be dissolved in 1 dm^3 of distilled water to make the stock solution of 1×10^{-3} mol dm^{-3} ABA. A common error was to just state the diluent as water rather than distilled or deionised water. The term 'dilute water' is not appropriate here. Some candidates suggested very large quantities of water (e.g. 1000 dm^3) that would be impractical or used very small masses of ABA that would be hard to measure accurately; these were not given credit.

(ii) Many candidates were able to correctly describe how to make a solution of 1×10^{-4} mol dm^{-3} ABA, by adding 10 cm^3 of the stock solution to 90 cm^3 distilled water. The other ABA concentrations in the range should be made by serial dilution; full credit was not awarded when candidates described a method using proportional dilution. Describing how to make the first solution, then stating 'repeat to make the rest of the solutions' was not sufficient to gain credit. A full method for at least one more solution in the range was required.

(b) (i) Most candidates correctly identified the independent variable as the concentration of ABA. The dependent variable was more challenging for candidates to identify. The number of germinated grains or the length of the shoot were both acceptable answers, as these could be measured during the investigation. Percentage or rate of germination were not given credit. A few candidates confused the independent and dependent variables.

(ii) Candidates were asked to describe a procedure to complete the investigation into the effect of different ABA concentrations on the germination of wheat grains. Therefore, repeating details such

as soaking the grains in a solution of GA, did not gain credit as this information was provided. A few candidates gained full credit for this question.

Some candidates had very little knowledge of how seeds are planted and watered in order to achieve germination. Few candidates used a container with soil or another suitable substrate for the wheat grains. It was also rare for candidates to consider providing water for the germinating grains; the same volume of water should be added each day. Several candidates included a control in their responses, replacing the ABA solution with distilled water.

Many candidates gave full answers that narrowly missed several of the marking points and achieved low scores due to a lack of precision. Carrying out the investigation in the dark was creditworthy, but maintaining a constant light intensity was not sufficient. The strongest responses kept the temperature for germination constant by using an incubator or a temperature-controlled room. A water bath would not be appropriate for this investigation. Comments about maintaining the temperature at around 15 °C or between 10 °C and 25 °C were too vague to gain credit.

The majority of candidates considered how they would measure the dependent variable, by counting the number of germinated wheat grains after a set time. An appropriate time scale would be from 24 hours up to a maximum of 7 days. Longer time intervals would result in full growth of the seedlings rather than observing germination. Several candidates gained credit by measuring the length of each shoot after a set time. Many candidates described replicates; this was not creditworthy as the information on page two had already established the use of large groups of 50 wheat grains for each ABA concentration.

Many responses incorporated some form of risk assessment, although stating that this investigation was 'low/medium risk' did not gain credit. Candidates should identify the hazard, state the risk associated with that hazard and clearly indicate the precaution that should be taken. For example, ABA is an irritant, therefore gloves and eye protection should be worn.

(c) (i) Candidates were asked to explain how the percentage germination was calculated; calculating a percentage increase in shoot length was not suitable. Many students correctly divided the number of germinated seeds by the total number of seeds and needed to add the instruction to 'multiply by 100' to be awarded the credit. Candidates should include all the necessary details for calculation questions.

(ii) Candidates were asked to sketch a graph, including labelled axes and values, to show the predicted results. Most responses included correctly orientated and labelled axes. A bar chart should not be used. Some candidates struggled to add values for ABA concentration to the *x*-axis; 1×10^{-7} mol dm^{-3} is smaller than 1×10^{-3} mol dm^{-3} and should therefore be placed closest to the origin. It was not necessary to use a log scale for the *x*-axis. The strongest responses added correct values to the *x*-axis and sketched a line with a descending trend.

(d) (i) Several candidates understood that a smaller standard error (SE) corresponds to a higher reliability, or vice versa; a clear comparative statement was required to achieve the credit. The strongest responses were able to describe how a smaller SE is linked with the degree of closeness of the calculated mean to the true mean. General definitions of SE were not sufficient to gain credit.

Some candidates quoted data to illustrate their point. To gain credit, data from **Table 1.1** needed to be quoted, including units for the GA concentration and an understanding of the reliability of the results, as shown by the SE values. For example, the most reliable data, with the smallest SE, is 1×10^{-7} GA. Several candidates thought about whether the SE values were overlapping, and a few candidates looked at the data in **Table 1.1** in sufficient detail. For example, strong responses identified the SE values that did not overlap and then stated that the difference in mean shoot length was significant.

(ii) Many candidates were able to give the correct null hypothesis, stating that there is no difference in the mean shoot length of the seedlings with no GA and 1×10^{-5} mol dm^{-3} GA. A common error was the omission of 'shoot length' from the null hypothesis. A few candidates incorrectly stated that there was no correlation rather than no difference or gave the alternative hypothesis.

(iii) Many candidates successfully stated that the calculated *t*-value should be compared with the *t*-value obtained from a critical value table. On occasion, candidates overlooked referring to the appropriate probability value ($p = 0.05$). Candidates usually noted that the null hypothesis should

be rejected if the calculated *t*-value is greater than the critical value. Candidates should remember that they are comparing two different values of *t*; stating that the calculated *t*-value is greater than *p* or 0.05 is not correct. The strongest candidates referred to the degrees of freedom, using the information from page five to correctly calculate the degrees of freedom as 38.

Question 2

(a) Most candidates who were able to secure credit for this question did so by referring to the limiting of mitochondrial protein denaturation. Some recognised that the buffer would also reduce the likelihood of the organelles bursting. Vague references to the rate of respiration slowing down did not attract credit.

(b) (i) The majority of candidates were able to correctly calculate the mean rate of oxygen consumption for mitochondria with succinate as 49.50 nmol min^{-1}. Some candidates inappropriately rounded this to one decimal place.

(ii) Most candidates were able to correctly identify both anomalous values in the table. If candidates are unsure, it should be noted that the mean value should not be selected.

(iii) Several candidates recognised that to process this data appropriately, anomalies should be excluded before calculating the mean. Alternatively, the experiment could be repeated to obtain replacement data, before calculating the mean. The strongest responses stated that further statistical analysis should be carried out. A high proportion of candidates misinterpreted the question and assumed it required an evaluation of the method; comments relating to air-tight containers, and other procedural issues were common.

(c) Candidates were asked to explain the results shown in **Fig. 2.2** and **Table 2.1**. Several candidates correctly stated that cyanide stops respiration, with some giving additional detail about the inhibition of the electron transport chain by cyanide. Several candidates also noted that respiration did not occur with mitochondria alone; to gain credit candidates also needed to state that there was no change in oxygen concentration (as shown by **Fig. 2.2**). Simply stating that the rate of oxygen consumption was low (using **Table 2.1**) was not sufficient, unless this was specified to be 'very low', or the mean value of 0.02 nmol min^{-1} was also quoted.

Adding succinate to the mitochondria will increase the rate of the Krebs cycle. Strong responses also noted that adding succinate and ADP will give an even larger increase in the rate of aerobic respiration. To secure these marking points, candidates needed to mention the idea of rate at least once. A few candidates made incorrect statements about glycolysis, which would not occur in isolated mitochondria. Several candidates linked the addition of ADP to oxidative phosphorylation and were able to gain credit by explaining that oxygen acts as the final electron acceptor.