BIOLOGY

Paper 9700/11
Multiple Choice

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

General comments

The paper differentiated well.

Comments on specific questions

Question 1

Over four fifths of all candidates incorrectly identified structure X as a ribosome. Ribosomes are typically about 25 nm in diameter whilst the diameter of structure X could be determined as somewhere in the region of 100 nm.

Question 2

The majority of stronger candidates answered correctly; half of the weaker candidates incorrectly suggested that the cell surface membrane could not form vesicles.

Question 3

Over four fifths of the stronger candidates and a third of the weaker candidates answered this question correctly.

Question 4

Over four fifths of the stronger candidates answered this question correctly and a fifth of the weaker candidates were able to do so.

Questions 5, **8**, **11**, **12**, **13**, **14**, **15**, **16**, **18**, **20**, **24**, **27**, **29**, **34**, **36**, **37**, **38** and **40**

A large proportion of weaker candidates and at least four fifths of the stronger candidates answered these questions correctly.

Question 6

Over three quarters of the weaker candidates incorrectly thought that the presence of a folded internal membrane supported the hypothesis.

Question 7

Almost all of the stronger candidates answered correctly, whilst over two thirds of the weaker candidates selected ribose or deoxyribose, which are not correct as viruses either contain RNA or DNA.

Question 9

Nine tenths of the stronger candidates answered correctly, whilst almost three quarters of the weaker candidates answered incorrectly, selecting options containing a peptide bond or a disulfide bond.

Question 10

Almost nine tenths of the stronger candidates answered correctly, whilst almost three quarters of the weaker candidates answered incorrectly, selecting options that included statement 2. Since the molecule contains six sulfur-containing amino acids the maximum number of disulphide bonds would be 3, not 6.

Question 17

Almost two thirds of all candidates incorrectly indicated that mitosis forms cells of equal size to the parent cell or that semi-conservative replication of DNA is part of mitosis.

Question 19

Almost all of the stronger candidates answered correctly, whilst over two thirds of the weaker candidates answered incorrectly, with two fifths selecting option **D**. Uracil is not a purine.

Question 21

Just over two fifths of all candidates answered this correctly. Almost three tenths of all candidates incorrectly selected option **A**.

Question 22

Three quarters of the stronger candidates answered correctly. Almost three fifths of the weaker candidates selected option **B,** meaning that they had not converted the DNA triplet ACA to the mRNA codon UGU.

Question 23

Whilst over nine tenths of the stronger candidates answered correctly, two fifths of the weaker candidates incorrectly selected option **D**. Phloem sieve tube elements do not contain a nucleus.

Question 25

Over half of the weaker candidates incorrectly selected options containing statement 3.

Question 26

Approaching three tenths of all candidates were able to process the information to answer correctly. Sucrose will dissolve in water and move in both the apoplast and symplast pathways.

Question 28

Over nine tenths of the stronger candidates and nearly a third of the weaker candidates answered correctly.

Question 30

Nearly two fifths of all candidates answered this question correctly. Three tenths of all candidates incorrectly selected option **B**. Proteins are present in blood and tissue fluid, although there are less proteins in tissue fluid.

Questions 31, 32 and 33

The majority of stronger candidates answered these questions correctly; the four options were selected almost equally by weaker candidates.

Question 35

Approaching three fifths of all candidates answered this correctly. The most common mistake was to include goblet cells.

Question 39

Over four fifths of the stronger candidates knew that the answer was T-killer cells. Almost half of the weaker candidates incorrectly selected neutrophils; neutrophils are the most common type of phagocyte.

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Paper 9700/12
Multiple Choice 12

Question Number	Key
1	B
2	B
3	B
4	B
5	C
6	B
7	D
8	B
9	B
10	D

Question Number	Key
11	B
12	A
13	A
14	C
15	C
16	D
17	C
18	A
19	A
20	D

Question Number	Key
21	B
22	A
23	B
24	B
25	C
26	B
27	B
28	C
29	A
30	C

Question Number	Key
31	A
32	B
33	B
34	A
35	D
36	C
37	C
38	D
39	D
40	B

General comments

The paper differentiated well.

Comments on specific questions

Questions 1, **2**, **4**, **6**, **7**, **8**, **9**, **11**, **15**, **16**, **17**, **21**, **22**, **24**, **25**, **26**, **29**, **33** and **35**.

The largest proportion of weaker candidates and at least four fifths of the stronger candidates answered these questions correctly.

Question 3

Nearly a third of all candidates answered this correctly whilst just under a third of all candidates incorrectly selected option **A**. mRNA is not found inside the rough endoplasmic reticulum, it attaches to ribosomes on the outer surface of the membrane.

Question 5

Whilst over seven tenths of the stronger candidates answered this correctly, over three quarters of weaker candidates incorrectly selected options which included the cellulose cell wall and/or chloroplasts, neither of which are found in prokaryotes.

Question 10

Almost all of the stronger candidates answered this correctly. Over a third of weaker candidates incorrectly selected options **A** or **C**. Cellulose contains β-glucose, not α-glucose. Additionally, over a third of weaker candidates incorrectly suggested that cellulose was a branched chain.

Question 12

Just over a quarter of all candidates answered this correctly. Almost two fifths of all candidates incorrectly selected option **B** and almost a third of all candidates incorrectly selected option **D**.

Questions 13 and **34**

At least three fifths of the stronger candidates answered these correctly; the four options were selected almost equally by the weaker candidates.

Question 14

Almost three fifths of the stronger candidates realised that the fastest rate would occur soon after the start of the experiment and that it would slow down as the substrate was used up. Almost a half of the weaker candidates incorrectly selected option **B** and three tenths of all candidates incorrectly indicated option **D** was true.

Question 18

Approaching three tenths of all candidates answered this correctly. In order for the dye to completely diffuse into the suspended block it only has to travel 2.5 mm from the surface of the block to reach the centre. This should take the same time as the 5 mm x 5 mm x 5 mm block. Almost three fifths of all candidates incorrectly selected option **B**.

Question 19

Whilst over four fifths of the stronger candidates answered this correctly, just over half of the weaker candidates incorrectly believed that the water potential of the cell was more negative, although over two thirds of the weaker candidates correctly realised that there would be a decrease in the volume of the vacuoles.

Question 20

Just over two fifths of all candidates could use the information to select the correct response. Almost a fifth of all candidates incorrectly selected option **C**, forgetting that the nuclear membrane disappears during prophase.

Question 23

Over nine tenths of the stronger candidates answered this correctly with seven tenths of the weaker candidates selecting the incorrect options.

Question 27

Approaching a third of all candidates answered this correctly. Whilst less than a fifth of all candidates incorrectly selected options containing the incorrect statement 4, over half of all candidates incorrectly suggested that passage of water through the apoplast did not involve mass flow.

Question 28

Less than a third of all candidates answered this correctly. The site of water evaporation during transpiration should be known as the mesophyll cell walls.

Question 30

Almost nine tenths of the stronger candidates answered this correctly. Two thirds of the weaker candidates correctly realised that the hair-like structures increased the internal humidity and half of these candidates also realised that the leaf shape helps to increase the internal humidity.

Question 31

Two fifths of all candidates could correctly equate a decrease in pH with the movement of protons (hydrogen ions) during the active loading of sucrose into companion cells.

Question 32

Nearly half of all candidates answered this correctly, with just over two fifths of all candidates incorrectly selecting option **B**. With the blood enclosed within the circulatory system in the human body at a temperature of about 37°C, the latent heat of vaporisation is not essential for its role in transport.

Question 36

Almost half of all candidates answered this correctly. A quarter of all candidates incorrectly selected option **B**, but the term endothelium is only used for blood vessels.

Question 37

Approaching a third of all candidates could use the information provided to calculate the shortest distance. The oxygen diffuses through the outer membrane of the alveolar cell, then through the cytoplasm, then the inner membrane of the alveolar cell. It then travels across the tissues between the alveolar wall and the capillary wall. Next it diffuses across the outer and inner cell membrane of the capillary as well as across the cytoplasm of the capillary cell. Finally, assuming that the red blood cell is touching the capillary cell membrane it has to cross the cell membrane of the red blood cell.

Successful candidates calculated the sum of the widths of these membranes and tissues to achieve the correct value of 605 nm.

Question 38

Less than half of all candidates answered this correctly. Statement 1 is about the lack of accessibility of the immune system to the pathogen. This does not explain why antibiotic treatment of TB takes a long time.

Question 39

Almost seven tenths of the stronger candidates answered this correctly. The most common error, made by almost two fifths of all candidates, was to base their answer on size alone and therefore select option **A**. When mode of transmission is also considered option **A** cannot be correct since the pathogens that cause malaria and cholera are not transmitted in the air.

Question 40

Nearly half of all candidates answered this correctly.

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Paper 9700/13
Multiple Choice 13

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

General comments

The paper differentiated well.

Comments on specific questions

Questions 1, **10**, **14**, **15**, **19**, **22**, **27**, **34**, **35**, **39** and **40**.

The largest proportion of weaker candidates and at least three fifths of the stronger candidates answered these correctly.

Questions 2, **3**, **7**, **18**, **20**, **31**, **33** and **36**

These were answered correctly by around two fifths of all candidates. Approximately four fifths of weaker candidates answered incorrectly.

Question 4

Whilst over seven tenths of the stronger candidates answered this correctly, over two thirds of weaker candidates incorrectly selected circular chromosomes or endoplasmic reticulum. Mitochondria and prokaryotes contain circular chromosomes so this is incorrect, and prokaryotes do not have endoplasmic reticulum so this is incorrect.

Question 5

Whilst four fifths of stronger candidates answered correctly, three quarters of the weaker candidates incorrectly thought that viruses contain polysaccharides.

Question 6

A third of all candidates answered this correctly. Circular DNA present in a bacterial cell, a chloroplast and a mitochondrion would not have telomeres since there are no ‘ends’ of the DNA.

Question 8

Almost two thirds of the weaker candidates incorrectly indicated that the glucose molecules in cellulose coil into a helix.

Question 9

Half of the weaker candidates incorrectly believed that triglycerides are polar molecules.

Question 11

Nearly a third of all candidates answered this correctly.

Question 12

Almost all of the stronger candidates answered correctly; nearly three quarters of the weaker candidates incorrectly selected either **A** or **C**.

Question 13

Just over two fifths of all candidates answered correctly, realising that disulfide bonds are also a type of covalent bond.

Question 16

Over a third of all candidates incorrectly selected option **B**. If enzyme Z is inhibited by the end-product there must be a decrease in the quantity of end-product.

Question 17

Three fifths of the weaker candidates incorrectly suggested that cholesterol only occurs between phospholipid heads. Additionally, three quarters of the weaker candidates incorrectly thought that at least some of the carbohydrate chains are mainly on the inside of the membrane.

Question 21

Over half of the weaker candidates incorrectly suggested that stem cells can repair damaged cells. They can be used to repair damaged tissue, but not individual cells.

Question 23

Nearly three fifths of the weaker candidates incorrectly thought that ATP contains deoxyribose instead of ribose.

Question 24

Whilst almost all of the stronger candidates could determine that strand 1 contains 3 cytosines, three quarters of the weaker candidates answered incorrectly.

Question 25

Less than half of all candidates knew the role of DNA polymerase.

Question 26

Over four fifths of the stronger candidates answered correctly. However, almost two fifths of the weaker candidates thought that the base sequence at S (tRNA) was the same as that on the mRNA.

Question 28

Approaching three tenths of all candidates answered this correctly. The majority of weaker candidates and a quarter of the stronger candidates incorrectly indicated that the answer was option **A**.

Question 29

Over half of all candidates incorrectly selected either option **A** or option **B**. Statement 1 applies to the apoplast pathway, not the symplast pathway and statement 2 is also incorrect.

Question 30

Whilst almost all of the stronger candidates could obtain the correct answer of 2400, less than three tenths of the weaker candidates could perform this calculation correctly.

Question 32

Whilst almost three quarters of all candidates realised that the correct *y*-axis label was hydrostatic pressure / kPa, less than three fifths of all candidates selected the correct *x*-axis label.

Question 37

Half of all candidates incorrectly believed that the photomicrograph was of a bronchus and not a bronchiole and almost three fifths of all candidates incorrectly thought the function of tissue P was to provide support and prevent collapse.

Question 38

Less than a third of all candidates selected the correct answer of 5. The oxygen molecule will pass through the cell membrane of the alveolar wall twice, then pass through the cell membrane of the cell in the capillary wall twice and finally once through the cell membrane of the red blood cell.

BIOLOGY

Paper 9700/21
AS Level Structured Questions 21

Key messages

Question 2(b), **Question 2(c)** and **Question 5(b)** asked for explanations of how structure is related to function. To be sure of gaining full credit in a response, candidates should address both aspects, rather than concentrate only on structure or only on function.

Candidates should be able to analyse and then describe graphs. When answering **Question 3(b)(i)**, many could have improved their response by using more appropriate vocabulary to describe the graph shown in **Fig. 3.2**. For example, a correct point would be to state that the rate of uptake of glucose increased steeply, rather than that the concentration of glucose increased steeply, and stating that at 150 $\mu mol\,dm^{-3}$ the uptake of glucose remains constant, rather than stating that it stops or stagnates.

Knowledge and understanding of the centromere and the centrioles is required. Candidates who wish to extend their learning should understand that the kinetochore is a different structure to the centromere and is not always an appropriate replacement term, as in **Question 4(c)(i)**. Similarly, centrioles are not the same as centrosomes, which means the centrosome is not always an acceptable alternative in a response.

General comments

Overall, there were some good answers to many of the questions on this paper, especially to **Question 3(c)(ii)** and **Question 5(c)(i)**. A number showed gaps in their knowledge about the structure of glycogen and cellulose in **Question 2(b)** and **Question 2(c)**.

Candidates should read all of the information given in the stem of each question carefully and study the details given in the stimulus material, such as graphs, images, flow charts and diagrams, as they should expect to make use of this information in their answers. Some candidates needed to look more carefully at **Fig. 5.2** before answering **Question 5(c)(i)**. A high proportion of those who did well in this paper had annotated the information in the stems of the questions, showing that they had taken time to read the material carefully.

Some answers were given as a list of terms and short statements in a random and unclear sequence. This was a particular problem with those writing their answers as bullet points. Time spent organising these points could have improved the quality of some responses. Precision is important when answering questions; for example, some candidates stated in **Question 1(a)(i)** that the cell in **Fig. 1.1** had few, rather than no, chloroplasts, and some stated that glycogen is 'more branched' than cellulose in **Question 2(a)**, implying that cellulose is branched.

Candidates should take care over spelling. Nucleolus was spelt in a variety of ways in **Question 1(a)(ii)**, and in **Question 5(a)** a number of candidates described the red blood cells as being 'bioconcave'. Quite a few candidates did not spell the term hydrolytic correctly in **Question 1(b)(ii)**. Some spellings meant that marks could not be awarded; for example 'microfibres' instead of microfibrils in **Question 2(c)**. Candidates confused lysosomes with lymphocytes and phagosome with phagolysosomes in **Question 1(c)**; some confused cytokine and cytokinesis in **Question 3(c)(ii)**. Abbreviations, such as HHb, should generally be avoided. If they are to be used then the term should be written in full with the abbreviation given in brackets as with haemoglobinic acid (HHb). Having stated the abbreviation like this it can then be used in the rest of the answer.

Comments on specific questions

Question 1

(a) (i) Some candidates noticed that the cell in **Fig. 1.1** has no chloroplasts and no large central vacuole but does have a centrally situated nucleus. A common error was to describe the vacuoles in the stem cell as air spaces. A high proportion of candidates gave differences between the stem tissue visible in the electron micrograph and mesophyll tissue in a leaf, rather than focusing on the cell as instructed. Comments about intercellular air spaces and xylem and/or phloem were common, indicating that candidates had missed the reference to the cell in **Fig. 1.1**.

(ii) A minority of candidates did extremely well in this question and completed **Table 1.1** correctly. The cell membrane was often given as the site of gas exchange and active transport (rows 1 and 3). 'Cell membrane' is ambiguous and the external membrane of the cell should be named as the cell surface membrane. There were several alternative answers that were accepted for row 3, including the tonoplast (**F** on **Fig. 1.1**), which was seen occasionally. However, many candidates wrote 'vacuole' rather than vacuolar membrane as an alternative to tonoplast. While many knew the names of the parts of the cell that carried out each function, they were less good at identifying the corresponding structure on the transmission electron micrograph in **Fig. 1.1**. Many identified the nucleolus (**C**) as the site of production of ribosomes and the mitochondrion (**E**) as the site of aerobic respiration. A common error was to identify **C** as the site of production of ribosomes, but to name it the nucleus. The mitochondrion was often given as **D** and the chloroplast was occasionally given as the site of aerobic respiration.

(b) (i) Endocytosis was given by many candidates. Phagocytosis and exocytosis were seen occasionally and were not accepted.

(ii) This question asked for a description of the breakdown of protein molecules. Many responses stated that this is carried out by hydrolytic enzymes, and a few used their knowledge of protein structure to state that peptide bonds are broken to release peptides and/or amino acids. Many candidates wrote about the mode of action of enzymes, including formation of enzyme-substrate complexes and the lock and key hypothesis, which was not required and so did not gain credit.

(c) There were some good descriptions of the role of lysosomes in fusing with phagocytic vesicles and releasing hydrolytic enzymes that break down any pathogens inside. Some candidates wrote about the role of macrophages, such as antigen presentation, and contrasted this with neutrophils, which was not the focus of the question. Weak responses incorrectly stated that lysosomes engulf pathogens or that lysosomes are enzymes, rather than stating that lysosomes contain enzymes. Some misread the question and wrote about lymphocytes.

Question 2

(a) There were some accurate answers given for this question. These frequently included clear comparative statements to be sure of gaining full credit. Generally, the bonding between α-glucose monomers was the feature that gave candidates most problems, with some not stating that the bonds are glycosidic bonds. As a consequence, stating that the bonds are 1, 4 and 1, 6 in glycogen did not gain credit. Some could have improved their description of the alternate rotation of β-glucose monomers in cellulose when they contrasted this feature with glycogen, where it is not present. Some suggested that cellulose has both α– and β–1, 4 glycosidic bonds and many thought that cellulose has 1, 6 glycosidic bonds, showing a lack of understanding of the numbering of the carbon atoms in glucose. Some candidates wrote about the features of cellulose molecules without contrasting them with glycogen, which meant that they were not answering the question. Some weaker responses described numbers of groups and individual atoms from the diagrams, some adding up the number of atoms. Others were very confused by **Fig. 2.1** and tried to answer the question by stating the positions of the hydroxyl groups.

(b) This question required candidates to relate the structure of glycogen shown in **Fig. 2.2** to its function. Many started their answer by stating that glycogen is a store of glucose or energy. The strongest answers went on to describe the highly branched structure shown in the diagram as having many terminals or 'ends' where glucose can be removed quickly or easily when required or can be added when glucose is in excess and is not required for respiration. Common mistakes included relating the branched structure to greater release of energy rather than release of glucose molecules, as the energy is not released until the glucose molecules are respired. References to insolubility appeared often and this was usually linked to an osmotic effect. Few candidates used water potential terminology. Instead, they often stated that glycogen has 'no osmotic effect' which was accepted. Many stated that the molecule is compact, without relating this to storage of glucose or energy; instead, they usually referred to it simply as taking up less space. Many described glycogen as containing amylose and amylopectin. Some candidates stated that glycogen was chemically inactive, and needed to explain why this is important.

(c) Good answers described the structure of cellulose in detail, for example by referring to the many hydrogen bonds between cellulose molecules, or the large number of –OH groups present, whereas many just wrote that there were hydrogen bonds. Some candidates incorrectly thought that cellulose is a fibrous protein and some suggested it is branched. There was some confusion with collagen as candidates referred to a 'triple helix' of cellulose molecules and the presence of covalent bonds between cellulose molecules and between microfibrils. Some suggested that cellulose is composed of amino acids. Careful reading of the question should have guided candidates to refer to cellulose molecules rather than cellulose fibres in cell walls or about the structure and function of cell walls. Some referred to 'β-pleated sheets' or 'polypeptide chains'.

Question 3

(a) Some candidates gave clear explanations of why membrane proteins are required for the movement of molecules such as glucose across cell surface membranes. The strongest answers stated that glucose is polar or water soluble and cannot pass through the hydrophobic core of the phospholipid bilayer. Most incorrect answers stated that glucose was too large. Some candidates stated that glucose could not travel through 'fatty acid tails'. Acceptable answers needed to make clear that there are two layers of fatty acid tails and often, in good answers, this was by the use of the term bilayer. Some stated that protein carriers are necessary because glucose is travelling against a concentration gradient into the cells, whilst others referred to needing channel and carrier proteins for facilitated diffusion. Occasionally there was confusion between hydrophilic and hydrophobic.

(b) (i) Some candidates recognised that the graph in **Fig. 3.2** is similar to graphs showing the effect of increasing substrate concentration on the rate of enzyme-catalysed reactions, and so used the term V_{max} in their answers, which was acceptable. They went on to state that the number of membrane proteins in the cell surface membrane of the yeast cells is the limiting factor for uptake of glucose when the rate of uptake is constant. Many candidates simply described the graph, often without units, and did not mention the membrane proteins or rate of uptake at all. Many did not state that a plateau was reached, so did not gain credit for the description. It was common to find descriptions of the reaction stopping or the rate reaching a peak instead of reaching a plateau or, in the best answers, that the rate became constant. Many candidates also suggested that increasing transporters which led to the increase in rate of uptake, was evidence of facilitated diffusion. Some thought that the membrane protein was an enzyme with an active site, rather than a carrier protein with a binding site.

(ii) There were many good answers to this question, with comments on increasing the sweetness of grapes and the extra energy available to support growth. Many also stated that improvements in the quality and size of the grapes would increase farmers' incomes or profits. Many candidates stated that the hexose transporters were used to move sucrose into the grapes, even though the information in the stem of the question stated otherwise. Some candidates wrote about the membrane proteins helping the growth of the grapevines rather than the grapes.

(c) (i) A few candidates gave a full definition of a non-self antigen and showed knowledge that the foreign substance is frequently a protein or glycoprotein that stimulates an immune response. Others gave only half a correct answer and needed to give further detail to gain credit. Some gave contradictory answers, showing an understanding that an immune response could be triggered but stating that the immune system did not recognise 'non-self'.

(ii) There were some excellent answers detailing the responses of lymphocytes to a specific antigen, with many gaining full credit. These answers began by explaining the role of T-cell receptors (TCRs) in clonal selection and activation of T-helper cells and T-killer cells. The functions of both types of cell were described well. Common errors included not making it clear that the T-cell receptors have shapes that are complementary to the specific antigen and stating that

T-lymphocytes become plasma cells and produce antibodies. Many candidates thought that T-lymphocytes differentiate into T-helper cells and T-killer cells only at the time when an immune response occurs. These types of lymphocytes differentiate during the maturation process in the thymus gland. Some incorrectly thought T-killer cells bind to and destroy pathogens directly rather than killing infected cells. Many also thought that T-killer cells inject toxins directly into the pathogen and that they 'kill antigens'. Many candidates wrote in detail about the role of B-lymphocytes including the formation of B memory cells, which did not answer the question.

Question 4

(a) Some candidates gave complete answers, reflecting a sound understanding of the meaning of the term gene. Others needed to include the sequence of bases or nucleotides in their answer and specify that it is part of DNA. Common errors were to give an explanation of the genetic code or describe a gene as a sequence of amino acids. Quite a few candidates referred to a gene coding for a characteristic rather than a polypeptide or protein.

(b) (i) Good answers did not confuse replication with transcription. The strongest accounts used **Fig. 4.1** to describe the movement of DNA polymerase along the leading and lagging strands, with the production of Okazaki fragments on the lagging strand being related to the role of DNA ligase. Although many stated that DNA polymerase catalyses the formation of phosphodiester bonds, few explained that activated nucleotides are added to the growing or elongating strand and that complementary base (or nucleotide) pairing occurs before phosphodiester bond formation. The proofreading activity of DNA polymerase was occasionally mentioned. Weaker responses referred to making mRNA or to DNA polymerase completing its activity at 'stop codes'. A proportion stated that phosphodiester bonds form between complementary bases. Some thought that DNA polymerase or DNA ligase unzipped DNA or formed the hydrogen bonds between the complementary bases.

(ii) Most candidates stated that DNA replication occurs in the S phase of the cell cycle. The most common mistakes were either 'G1 phase' or writing S or synthesis without adding the word 'phase'.

(c) (i) There were many good answers to this question. Common errors were to name **A** as a centrosome or kinetochore rather than as a centromere and stating that spindle fibres pull chromatids to the 'sides' of a cell rather than to the poles. Many candidates did not make it clear that the centromere holds sister chromatids together and quite a few candidates just referred to the chromatids being pulled apart without being more specific as to when this happens and the destination of the chromatids.

(ii) Many candidates misunderstood this question. Instead of drawing one pair of daughter chromosomes (sister chromatids) during anaphase, they drew two, three or more pairs of daughter chromosomes. Others showed a misunderstanding of the term 'chromosome 11' in the question and drew 11 pairs of chromosomes. Some candidates could have improved their response by drawing in the spindle fibres or drawing them from the centromeres all the way to the poles. A number could have added the centromere on each daughter chromosome.

Question 5

(a) Most candidates gave two features of red blood cells that are visible in **Fig. 5.1**. Common answers were biconcave shape and no nucleus. Some candidates stated that red blood cells are flexible, but all that can be seen in the electron micrograph is that the cells have different shapes, and they are not all biconcave. 'Flexible' on its own was not accepted. Many stated that the red blood cells are the same diameter as the capillary rather than the same diameter as the lumen of the capillary. It was common to see the diameter of the cells stated as 7 nm rather than 7 μm. Although many knew the diameter of red blood cells, this could have been calculated using the magnification given on **Fig. 5.1**. The weakest candidates wrote about the numbers of cells and their dark appearance.

(b) Many candidates gave good answers to this question about the capillary wall. The most common answers referred to the wall as thin, to provide a short diffusion distance. Many missed the importance of the word 'wall' in the question as they wrote about the size of the lumen and the functions of capillaries. These answers were not relevant. A common error was to describe the wall as being composed of squamous epithelial cells, rather than being composed of endothelial cells. Others stated that there were pores, holes or gaps in the wall without any reference to them being within or between the cells in the wall. Some good answers referred to these pores as fenestrations.

(c) (i) This question on transport of carbon dioxide proved more challenging. Good answers often started with identifying the question as being about the Bohr shift. Many candidates needed to appreciate that with an increase in carbon dioxide in the blood, more carbon dioxide diffuses into the red blood cells, and more carbon dioxide reacts with water to form carbonic acid. Candidates who made it clear that this happens often accessed full credit. Some candidates wrote about the binding of carbon dioxide to haemoglobin and a few stated that the molecules bind to the N terminals of the four polypeptides. Some thought that carbon dioxide binds to haem groups. The weakest answers did not mention haemoglobin and often referred instead to carbon dioxide binding to red blood cells.

(ii) There were many excellent accounts of the chloride shift. Candidates who realised that this was a question on the chloride shift described and explained the movement of the ions involved. However, some wrote that chloride, or even chlorine, enters the red blood cell to balance the hydrogen ions formed when carbonic acid dissociates. Candidates must always include the word ‘ion’ when writing about the transport of carbon dioxide and the chloride shift.

Question 6

(a) Most candidates identified **X** as a plasmodesma. The plural term, plasmodesmata should not be used to describe a single structure.

(b) Many candidates identified **Y** as the Casparian strip, often misspelled as ‘Casperian’. Suberin was often given, and candidates who wrote both terms gained credit. Suberin on its own did not gain credit.

(c) This question was poorly answered. Many candidates gained credit only for osmosis on the first line. Some wrote several answers in each space and some wrote osmosis on each line. A common answer for the second space was ‘transpiration’ rather than ‘transpiration pull’. Many did not state that water moves from mesophyll cell walls to intercellular air spaces by evaporation. Diffusion was the most common incorrect answer.

BIOLOGY

Paper 9700/22
AS Level Structured Questions 22

Key messages

Question 1(a) required candidates to use the terms systole and diastole to complete **Fig. 1.1**. These terms are included in a learning outcome in syllabus Topic 8, Transport in mammals. Candidates need to be familiar with their meaning when they appear in the text of a question. They should also be confident using the terms when including them in their answers, such as in **Question 1(b)** and **Question 1(c)**.

Candidates should remember that eukaryotic organisms can be unicellular or multicellular. The nuclear envelope of the (true) nucleus of *Trypanosoma brucei* was very evident in **Fig. 4.1** and provided confirmation that the organism is a eukaryote. Despite this, in **Question 4(a)(iii)**, some were influenced by the unicellular nature of the organism to state that *T. brucei* is a prokaryote.

Some questions require the different nitrogenous organic bases or the different nucleotides of DNA and RNA to be named as part of a response. Candidates must learn the correct spellings for these bases and should not rely on phonetic spellings. Care should also be taken to avoid stating the nucleoside instead of the base. In **Question 5(a)**, cytosine and thymine were frequently spelled incorrectly and adenosine was occasionally seen instead of adenine.

General comments

A good proportion of candidates were well prepared for this examination. There was evidence that many had given equal weighting to the syllabus topics when revising, which resulted in a balanced performance. The extended response of **Question 5(b)(iii)** was, for many, the most challenging item on the paper. There were also some questions where a number of candidates missed the focus and gave some good biological answers for a slightly different question, which meant that little or no credit could be given. This was particularly notable for **Question 2(b)** and **Question 2(d)(iii)**.

Question 1(b) and **Question 1(c)** assessed understanding and knowledge of the control of the cardiac cycle and blood pressure changes during the cardiac cycle. Some gave responses that were mainly descriptions rather than explanations, even though the command term used for both questions was ‘explain’.

In Question 2(a), candidates used **Fig. 2.1** to give observable differences between root apical meristem cells and root cap cells. Some wrote about the different locations of the two cell types, which was not credited because the introduction to the question had already stated that there were two different regions shown in the root tip.

In **Question 3(b)**, many candidates followed the instructions and understood that **Table 3.1** should be completed so that all boxes (cells) in the table contained a tick or a cross. Some used only ticks, or only crosses, or used ticks and crosses and left some empty boxes. It is important that candidates comply with the instructions given in the question.

Question 4 used an unfamiliar context of sleeping sickness caused by *Trypanosoma brucei* to assess two syllabus topics: Topic 1, Cell structure and Topic 10, Infectious diseases. Candidates needed to apply syllabus knowledge and understanding to answer **Question 4(a)** and **Question 4(c)**. Many realised the paragraph at the beginning of **Question 4** contained all the information required to add to their knowledge of malaria to formulate a response to **Question 4(c)**, while others missed these details and gave incorrect responses.

The extended response to **Question 5(b)(iii)** highlighted that some candidates had a good grasp of DNA replication while others needed to improve their ability to distinguish between DNA replication and DNA transcription. Although this question required candidates to focus on DNA polymerase, some responses included roles associated with transcription and RNA polymerase.

In **Question 6(c)(i)**, many candidates were successful in extracting comparative values from the data in **Fig. 6.2** to help support their response. Others would have benefited from double checking the *y*-axis value. Five small squares were the equivalent of 0.2 cm, which meant that each small square was 0.04 cm. Some read up from the printed value on the *y*-axis and incorrectly added 0.02 for each small square.

Comments on specific questions

Question 1

(a) Candidates needed to use their knowledge and understanding of the cardiac cycle to complete the boxes in **Fig. 1.1** correctly. Most followed the instruction to use only the terms systole and diastole; there were some who gave the terms contraction and relaxation. Some did not show an understanding that atrial systole and ventricular systole should not occur at the same time. There were some responses that completed each box the wrong way round.

(b) Many knew that the delay at the AVN would prevent atrial and ventricular systole from occurring at the same time. Stronger responses gave further detail, either by explaining that ventricular systole occurs after atrial systole and/or noting that the delay allowed the atrium to empty and the ventricle to fill before ventricular systole. Some misunderstood the question and gave a description of the sequence of events involving the SAN and the AVN. Weak responses suggested the delay was to prevent backflow of blood or allow time for valves to open and close.

(c) Those giving a complete explanation of how blood pressure changes cause the opening of the tricuspid valve considered the relative blood pressures either side of the valve, rather than just stating the valve would open when pressure increased in the right atrium. Fewer wrote that the pulmonary valve opened when the pressure in the ventricle exceeded the pressure in the pulmonary artery. There were a number of different ways to explain how the changes helped the flow of blood through the heart and most were able to gain credit, usually explaining how the opening and closing of valves prevented backflow. Some incorrectly related the tricuspid and pulmonary valves to the left side of the heart, or wrote about the pulmonary valve opening so blood could flow to the aorta.

Question 2

(a) Candidates were given three prompts in the answer lines to organise their response into three differences between root apical meristem cells and root cap cells. There were some very clear answers where, for each prompt, only one feature was considered and the two different cell types were identified and linked to a good description to show the difference. Differences in overall size of the cell types and the shapes of the cells were commonly stated. Many chose to make a comment about the nucleus in the two cell types. Those who gained credit realised that this was not a difference in observed size of nucleus, but a difference in size of nucleus in proportion to the size of the cell. Fewer noticed that there were a number of root apical meristem cells in stages of mitosis, compared with no root cap cells in mitosis. Weaker responses gave a mixed comparison, for example stating that root apical meristem cells were arranged regularly and comparing this with large root cap cells.

(b) This was a question, based on unfamiliar material, assessing knowledge and understanding of the cohesive and adhesive properties of water. Some gave excellent accounts, correctly applying knowledge to write about the small clumps of soil formed as a result of the action of mucilage. Others concentrated their efforts to write about how root tips help to maintain water, rather than the soil clumps, which was not the focus of the question. Some confused adhesion with cohesion, or did not include the detail that water molecules are involved. Very weak responses did not address the theme of the question and gave accounts of water movement within the root tip or stem.

(c) The correct term extracellular was given by most candidates.

(d) (i) There were many different ways to gain full credit for an explanation of a polysaccharide. Common errors included stating two or more, rather than more than two monosaccharides, and to use the term ‘monomer’ without further qualification. Some gave a correct statement but then included reference to amino acids or gave an incorrect bond type.

(ii) There were some very clear drawings of the general structure of an amino acid. Labelling of the different parts was not required, but if the R group was labelled and annotated correctly, credit was given for the explanation of how it is possible to have many different amino acids. It was not acceptable to have NH_2 – written on the left and shown joined to the central carbon, but H_2N was credited. One error was to show three, rather than two, hydrogen atoms attached to the nitrogen. Some gave H instead of R, which meant that they drew a glycine amino acid rather than the general structure.

(iii) Candidates generally showed a good understanding of how an increase in mineral ions within a root hair cell would affect water potential and increase the absorption of water. Many were able to gain full credit. Some showed a lack of understanding of the difference between water potential and water potential gradient. Others could have improved their answer by using the terms water potential instead of concentration of water and water potential gradient instead of concentration gradient. There were a number who did not read the question carefully enough and gave a detailed account of mineral ion uptake by root hair cells.

Question 3

(a) Some candidates gave excellent outlines of the features of non-self antigens, including more details than were required to gain full credit. Others gave confused accounts, which sometimes included contradictory statements and highlighted the need for improvement in this area. Two common misunderstandings were to equate a non-self antigen with a virus or a complete cell such as a bacterial pathogen and to state that receptors are present on antigens. It was also common for a candidate to state that a non-self antigen was not recognised by the body, but then later in their answer to state that an immune response occurred in the presence of the antigen.

(b) Knowledge of the cell types of the immune system was the main focus of this question. The column relating to B-lymphocytes was generally completed correctly. Many mistakenly suggested that the plasma cell was able to go through clonal expansion. The most common correct row was to match the description ‘main role is to secrete cytokine during an immune response’ with the T-helper cell.

(c) Most responses completed sentences **B** and **C** correctly. There were alternatives to gain credit for sentence **C**, although it was not acceptable to state another event in addition to DNA replication, because this sentence began with ‘The main event ….’. Stating cell division to complete sentence **A** was not enough to gain credit. A number of candidates incorrectly stated interphase or G1 phase.

Question 4

(a) (i) The nucleolus was very visible within the nucleus in **Fig. 4.1** and many were able to draw an arrow to the nucleolar area. Arrows that ended within the nucleus but not extending to the nucleolus did not gain credit. Some candidates did not attempt to add an arrow on **Fig. 4.1**.

(ii) Candidates who closely examined structure **X** on **Fig. 4.1** could see a resemblance to a transverse section of a cilium and made reference to microtubules and to the 9 + 2 microtubule pattern to gain full credit. For the requirements of the syllabus, the suggestion that structure **X** was a cilium was given credit. Some used knowledge beyond the syllabus and stated correctly that the structure was likely to be a flagellum. Many did not refer to the microtubules within structure **X** and related the idea of movement in *T. brucei* to the process of endocytosis or phagocytosis.

(iii) Candidates needed to study **Fig. 4.1** to decide whether *T. brucei* is a eukaryote or a prokaryote. The most outstanding feature in the electron micrograph confirming that the organism is a eukaryote is the large nucleus with the obvious nuclear envelope. The answer to **Question 4(a)(i)** should also have assisted them with their response. Some realised that the presence of microtubules or the 9 + 2 pattern was consistent with a eukaryotic feature. Having identified the cell as a eukaryote, some candidates looked for additional eukaryotic cell structures and suggestions of structures resembling endoplasmic reticulum, a Golgi body and mitochondrion were also accepted. The single mitochondrion of *T. brucei* is unusual and it was not expected that candidates identify this. For this reason, the plural ‘mitochondria’ was allowed because a number of structures in **Fig. 4.1** could be mistaken for these organelles. If candidates did not note the nucleus and mitochondrion in **Fig. 4.1**, but stated that there were organelles bound by a double membrane, then credit was given. No credit was given for organelles bound by a single membrane as these are known to be present in prokaryotes.

(b) (i) Most knew that the term 'pathogen' describes an organism that causes disease.

(ii) For the causative organism of malaria, only one species name was required to accompany the genus *Plasmodium* that had been given on the answer line. All four species names stated in the syllabus were seen, with malariae and falciparum being the most common. Spellings were frequently correct.

(c) A good proportion of candidates achieved full credit by stating correct similarities and differences between the modes of transmission of malaria and sleeping sickness. The term vector was usually used in a correct context and often candidates realised that the vector of each infectious disease feeds on blood. Well-expressed answers gave clear comparative statements for the differences. Some did not realise that a mosquito is an insect and incorrectly stated that the vector of sleeping sickness is an insect, whereas the vector of malaria is a mosquito. Weak responses confused the causative organisms of the disease with the vectors or had not referred back to the information provided at the start of **Question 4**, and gave incorrect suggestions for some of the features of sleeping sickness. Some thought that malaria was transmitted by aerosol infection.

Question 5

(a) Many gained full credit for correctly completing **Table 5.1**. Where partial credit was given, this was often for incorrect spellings of the names of the bases. Some also stated other molecules, such as the vitamin thiamine for thymine, the amino acid cysteine for cytosine and the amino acid glycine for guanine.

(b) (i) Many candidates correctly made the link between the double ring structure in carbovir triphosphate and purine nucleotides.

(ii) Candidates needed to refer back to **Fig. 5.1** to see that carbovir triphosphate has a structure more closely resembling an activated purine nucleotide than abacavir and so would be more likely to be mistaken for a DNA nucleotide and added to the polynucleotide chain. Many noted the addition of phosphate groups in their response or gave a detail of DNA polymerase action and polynucleotide chain formation. Some weak answers described the phosphate groups as phosphate heads, confusing the structure with a phospholipid. Very few commented on the loss of the triangular section from abacavir, which would make carbovir triphosphate more suited to fit the active site of DNA polymerase.

(iii) Candidates were not expected to know how carbovir triphosphate acts as a therapeutic drug to prevent viral DNA synthesis, and all reasonable suggestions were credited. Those who did well showed an understanding that, although carbovir triphosphate can substitute for a DNA nucleotide during the replication of DNA, its insertion into the polynucleotide chain would somehow prevent the formation of the viral polynucleotide strands. Some candidates used knowledge of enzyme action, enzyme inhibition and the role of DNA polymerase in the process of DNA replication to suggest that the nucleotide analogue acted as an inhibitor of the DNA polymerase enzyme. This was accompanied with details of a possible mechanism of action. Candidates who knew details of DNA replication were not distracted by the additional two phosphates, knowing that this represented an activated free nucleotide similar to those that are inserted into a growing polynucleotide chain. Those who had less of an understanding suggested that the analogue was too long to fit in position correctly, not realising that the additional phosphates are required as preparation for phosphodiester bond formation. Some candidates had difficulty distinguishing between transcription and replication, and wrote about stop codons and frameshift mutations. It was also quite common for candidates to use the term 'base' instead of 'nucleotide' throughout their response.

Question 6

(a) Most could use **Fig. 6.1** to deduce that the airways in generation 1 were the bronchi. A number gave the singular 'bronchus', which was allowed. Very poor spellings, which could have been either bronchi or bronchioles, were not credited.

(b) Candidates were not limited in the number of different suggestions they could make as to why the airways from generation 0 to generation 16 are not able to carry out gas exchange. Many suggested that the diffusion distance was too great and qualified this with an outline description of the histology of the wall of the airways, or stated that the squamous epithelium found in the alveoli was absent. No credit was given for stating that the alveoli were not present in these airways. Candidates were informed at the beginning of the question that the airways were well supplied with blood, so suggestions of no blood supply were incorrect. Other relevant ideas put forward were credited, such as a lack of deoxygenated blood to allow diffusion to occur.

(c) (i) Many stated a clear and correct relationship for the Weibel Lung model data in **Fig. 6.2**, for example: 'As airway generation increases from generation 0 to 5, airway diameter decreases.' Others were less clear in their description of increasing airway generation: 'As you go along the airways..' or 'As you go across the airways…'. Weak responses made an observation, such as 'the lowest airway has the widest diameter', rather than stating a relationship.

(ii) Some candidates used the data in **Fig. 6.2** effectively to make a decision as to whether HP gas MRI could be a useful alternative to HRCT. Their decision was supported by making observations about the data in **Fig. 6.2** and by extracting accurate comparative values. There were also some excellent responses that gave relevant explanations for supporting, and for not supporting, HP gas MRI as a useful alternative. Stronger candidates understood that the measurements in **Fig. 6.2** for the two MRI image types were being compared to the standard, which were the Weibel lung model results. This was stated in the information provided and was shown in the key below the bar chart. Some candidates would have benefited from re-reading this information, as there were a number who mistakenly thought that the third set of results were HRCT measurements. Others gave approximate readings from **Fig. 6.2**, which were not credited.

BIOLOGY

Paper 9700/23
AS Level Structured Questions 23

Key messages

Question 1(a)(ii) required candidates to describe the behaviour of chromosomes during the anaphase stage of mitosis. Some were able to give a clear description of this stage by using the term sister chromatids when describing the start (onset) of anaphase, followed by daughter chromosomes for the remainder of the stage. Sister chromatids can be thought of as structures that share a centromere as part of a chromosome. Sister chromatids that have separated as a result of the division of the centromere, and each now have their own centromere as they move to opposite poles, can be described as daughter chromosomes.

For some questions, candidates are required to make measurements of length to calculate a magnification of an image or to determine an actual size. Frequently a conversion to micrometres (μm) must be made at some stage in the calculation, such as in **Question 3(a)(ii)**. In instances such as this, it can be beneficial to take measurements in millimetres (mm) and not in centimetres (cm). A number of candidates, who knew to multiply mm by 1000 to obtain micrometres (μm), then did not multiply their measured cm value by 10 and so arrived at an answer of ×150 instead of ×1500.

Candidates need to be able to distinguish between translation and post-translational modification. In **Question 6(b)**, some candidates began their response by stating that glycoproteins were synthesised at the ribosomes, rather than separating the process into the synthesis of a polypeptide and the events that occur after translation to produce the functioning glycoprotein.

General comments

At all levels of ability, there were candidates who had prepared very well for this examination and gave a very good all-round performance. Gaps in knowledge shown by others were frequently for subject matter that is commonly found to be more challenging and hence more difficult to assimilate. Those candidates could have benefited from learning the more simple main points concerned so that they were able to give an outline overview when answering a question. This would have allowed them to tackle some of the extended responses in this paper more effectively, such as **Question 3(b)(i)**, **Question 4(b)(ii)** and **Question 6(b)**.

Repeating information provided in a question will only be credited when it is accompanied by further detail. In **Question 1(b)(ii)**, some candidates simply repeated that telomerase helps to maintain telomeres. To give a good response to the question posed, this needed to be qualified with a correct idea associated with longevity.

In questions such as **Question 2(a)(i)**, it is important that candidates double check that they have correctly worked out how much one small square is worth for each of the axes on a graph and have extracted the correct data from the graph. Almost all candidates understood what the question was asking, and some could have been more successful if they had taken the time to check their response for accuracy in the data quoted.

During the AS course, candidates may have the opportunity to view a range of prepared microscope slides, such as those showing stages of mitosis and blood smears. To consolidate learning and revision and increase their confidence when answering questions, candidates could use images of photomicrographs and electron micrographs available on the internet to continue to practise observation and identification of cells and cell structures.

For those candidates who had good knowledge and understanding of immunology in **Question 4(b)(ii)**, the quality of response was still very varied. The stronger responses tailored their answer to match the question posed about producing antibodies. Others gave a more general account and gave details of an immune response which were not always relevant to the question.

Question 5(b)(i) demonstrated the importance of reading the question posed at least twice to be sure of selecting the correct ideas when answering. There were many who did not do this and who gave biologically correct sequential accounts highlighting the role of companion cells in loading sucrose into sieve tubes, taking up all the answer lines provided, rather than describing the transport of sucrose in phloem sieve tubes. The only credit that could be given was when the response went on to include transport within sieve tubes, which was then answering the question posed.

Comments on specific questions

Question 1

(a) (i) Most candidates correctly identified the stage of mitosis in cell **B** as prophase. The stage of mitosis for cell **C** was sometimes identified as anaphase, rather than metaphase. This may have been because some of the darkly staining structures had a slight 'V' shape, but for anaphase these would not have been layered on top of each other.

(ii) It was not necessary to identify the stage of mitosis in cell **A** as anaphase. Some responses were unambiguous, showing an understanding that anaphase began with the separation of sister chromatids and making it clear that these moved to opposite poles of the cell as daughter chromosomes. A few gave more detail and described the division of the centromere at the start of anaphase. Many understood that the spindle fibres were involved in the movement of daughter chromosomes. Stating that the daughter chromosomes moved to opposite ends of the cell was too imprecise to be credited. Weak responses needed to distinguish more clearly between sister chromatids and chromosomes. Some used the terms pairs of chromosomes or homologous chromosomes.

(iii) There were some very concise and accurate accounts of the role of DNA ligase. These contrasted with responses that confused ligase with helicase or suggested that the enzyme was responsible for proofreading. Ligase and DNA polymerase are both involved in the formation of phosphodiester bonds between nucleotides, so stronger responses made it clear that ligase only acted on the lagging strand to seal Okazaki fragments. Some missed the information about interphase and stated that ligase acted during mitosis.

(b) (i) The location of telomeres on a chromosome was well known by most candidates. Some misread the question as asking for the location of the chromosome, so gave 'nucleus' as the answer.

(ii) Generally, there was a good understanding that telomeres help prevent the loss of DNA during replication. Because telomeres can be described as genetic material, stating that they helped prevent the loss of genetic material was not precise enough; accurate answers used the term genes or genetic information. Some were able to give additional detail to complete their answers, usually by explaining that more cell division could take place.

Question 2

(a) (i) It was possible to gain full credit in this question by stating the main trend shown in the number of reported cases of TB in the 20-year period and by giving more details of trends within this time. This included extracting data from **Fig. 2.1**. More successful candidates had carefully worked out the scale of the axes of the graph, particularly the *y*-axis, where each small square was the equivalent of 400 reported cases. There were many who mistakenly used 200 reported cases per square. Candidates needed to give precise extracted values rather than using terms such as 'around', 'just above' and 'just below'. There were also errors made quoting the correct year.

(ii) A high proportion of candidates made a link between HIV-infected people and a weakened immune system and related this to an increase in the number of cases of TB. Fewer went on to provide more detail of a specific feature concerning the immune system as further explanation.

(b) There were some knowledgeable answers given, with the most common credited responses recommending minimal use of antibiotics and being sure to complete a course of antibiotics. A large number also used knowledge of the control of TB and suggested using combination therapy.

Some gave vague statements suggesting either giving stronger or weaker doses of antibiotics, which were not credited.

(c) (i) Good answers stated that damaged cartilage could make the bronchi collapse, or gave a description of this based on the idea of a lack of structural support. Answers not credited because of a lack of detail included stating that the bronchi would be weaker, or that air would not be able to pass through. Some incorrectly stated that they would burst.

(ii) Most followed the instructions given to complete **Table 2.1** using ticks and crosses. A number used only ticks and left other boxes blank. Some candidates completed all of **Table 2.1** correctly. For those who gained partial credit, knowledge of the distribution of cell types was better for the alveolus than for the bronchus and trachea, although there were some who suggested that smooth muscle cells were present in the alveolus.

Question 3

(a) (i) For well-prepared candidates, **X** was usually correctly named as a neutrophil. These candidates went on to identify **Y** either as a monocyte or as a lymphocyte. It was reasonable to consider the cell to be a monocyte rather than a lymphocyte because its size was considerably larger than the size of a red blood cell. However, the lack of an obvious kidney-shaped nucleus and the presence of what seemed to be a large spherical central nucleus directed some candidates to identify the cell as a lymphocyte, despite its large size. No information about the source of the blood was provided, so candidates did not know which species was represented and both suggestions were considered to be creditworthy. Stating that **Y** was a macrophage was not credited. Some candidates were unable to name the particular blood cell types, so 'white blood cell' for **X** and 'red blood cell' for **Y** was seen, or vice versa. The weakest responses had missed the information that the photomicrograph showed different types of blood cell and named cell types other than those in blood, or suggested stages of mitosis.

(ii) This was a straightforward calculation and candidates did not need to show their working. For full credit, the formula used to make the calculation and the correct calculated value were required. Some arrived at the correct calculated value and needed to write in the formula for full credit, or used the box only to show working. A number of candidates measured the line **Z** in cm and omitted to multiply by 10 to get mm before multiplying by 1000 to get µm. This meant that when they divided by the actual value of 8 µm, their answer was out by a factor of 10. Some candidates gave an incorrect formula or made an error in calculation and arrived at a value for the magnification that was clearly not credible; this should have alerted them to rethink their answer.

(b) (i) Some candidates were able to organise their response so that events were sequential and more than enough detail was provided to gain full credit. Others who gained some credit gave details of the reaction catalysed by carbonic anhydrase and then were confused as to how this would lead to the release of oxygen. Some knew that hydrogen ions would bind to haemoglobin and needed to go on to state that haemoglobinic acid was formed. Others had the incorrect idea that the enzyme directly catalysed the release of oxygen from haemoglobin.

(ii) Most drew a curve below the printed curve on **Fig. 3.2** to gain credit. The clearest curves ended up at the same maximum rate of reaction as carbonic anhydrase without inhibitor or closely approached the maximum. There were a number who went above the maximum or who drew the curve for a non-competitive inhibitor.

Question 4

(a) (i) Candidates had to apply their knowledge of the levels of protein structure to match the descriptive statements in **Table 4.1**. Many found this challenging. The third description included the term β-pleated sheets, which helped candidates correctly match this to secondary structure. There were fewer who could match the other two descriptions to the correct level of structure. Forming a compact structure was indicative of either tertiary or quaternary structure, but the fact that gliadin was described as a single polypeptide should have guided candidates to exclude quaternary level.

(ii) Some candidates understood that introns are non-coding sequences, and knew that RNA splicing needed to occur to produce mRNA. This allowed them to reach the assumption that the RNA transcribed from a gliadin gene would not need this post-transcriptional modification. It was also important to understand that the absence of introns in the gliadin gene was a natural phenomenon. Some candidates incorrectly assumed the absence would result in a negative effect and suggestions such as a decrease in the rate of transcription, slower production of mRNA and mRNA with a different sequence were seen.

(b) (i) The length of the gliadin peptides and the quantity in which they are taken up by intestinal cells helped candidates to deduce that peptides are transported into intestinal cells by endocytosis. Most who stated this mechanism were able to give some further detail to gain full credit. Some considered that the peptides could be hydrophilic and suggested active transport or facilitated diffusion. Although this was a far less likely suggestion, reference to either of these was also credited.

(ii) There were some excellent answers to this question. The correct scientific terminology was used and the events were given in sequence; all of the required detail was included and the responses were concise with no irrelevant information. Weaker responses confused the sequence in which events occurred or continued the description to include the production of memory cells and the secondary immune response. Many knew that plasma cells produce antibodies but were less clear in explaining that these developed from B-lymphocytes following clonal expansion. It was also common for candidates to erroneously state that T-lymphocytes produce antibodies. Some candidates did not realise that this was a question about the immune response and gave accounts of cell signalling, using gliadin as the cell signalling molecule and stating antibody release as the final response.

Question 5

(a) A larger proportion of candidates correctly identified the xylem tissue in **Fig. 5.1** than the phloem tissue. It was common to see the darker area of sclerenchyma, nearest to the periphery of the vascular bundle, labelled as phloem tissue. Completely incorrect answers had no labels to any part of a vascular bundle. Here, they gave a label with either xylem or phloem to the darker outer region and the other label to the inner, more central, lighter region.

(b) (i) Good answers focused on transport of sucrose in phloem sieve tubes and included enough descriptive comments in a logical sequence to gain full credit. For many who wrote at length about companion cells, there was only a sentence at the end mentioning mass flow or stating that entry of sucrose lowered water potential. Some could have improved the construction of their response to show sound understanding of the topic. For example, ‘sucrose diffuses from companion cells into phloem’ implied that the candidate did not know that companion cells are included in phloem tissue. Some stated that sucrose moves from the photosynthesising leaf into the source or into phloem sieve tubes, which implied that the candidate did not know that the phloem is within the leaf and that the leaf is the source. Many knew that water entry into the phloem sieve tubes at the source increased hydrostatic pressure. Fewer continued with the idea that the sink had a lower hydrostatic pressure or that transport of sucrose was down a hydrostatic pressure gradient. The weakest responses described active transport or diffusion within the sieve tubes.

(ii) It was necessary in this question to start with the concept that the presence of cyanide ions has a negative effect on respiration. Some candidates did this and so began by explaining that less ATP would be available as a result. This allowed them to follow up with one or more examples showing that the end result would be less sucrose being transported into phloem sieve tubes. Many incorrectly concentrated on photosynthesis and thought that cyanide ions affected this process, or that the ions interfered directly with the proton pumps of companion cells. A common misconception was that respiration involved the synthesis of glucose, which was required for sucrose synthesis.

(c) In this question, candidates could be credited for choosing either solution **A** or solution **B**, if this was then qualified with some correct biological detail. Some candidates gave confident responses, realising that the solution they had chosen would have more reducing sugar and went on to explain that sucrose is a non-reducing sugar and so would not result in Benedict’s solution changing colour. Some needed to relate their choice to the Benedict’s test. There were many who made the mistake of stating that sucrose is a reducing sugar.

Question 6

(a) Strong responses demonstrated their knowledge of glycogen and used **Fig. 6.1** to set out three clear differences between nystose and glycogen using comparative terminology. A number of these made reference to the three fructose residues in **Fig. 6.1** and were able to deduce that the other monomer was α-glucose. The most common correct answer was that nystose is not branched, compared to the branched structure of glycogen. An extremely wide range of ideas were put forward that were not creditworthy. Of these, a common incorrect idea put forward for either glycogen or nystose was that β-glucose is present. Where it was stated for glycogen, candidates also described features of a cellulose molecule, writing about the alternate orientation of the glucose residues. Many noticed the three five-sided and one six-sided ring shapes in nystose but very few stated this and most converted the observation into pentose and hexose sugar differences, which was incorrect.

(b) The most fluent answers used correct scientific terminology and gave concise descriptive accounts that were in a logical sequence. Many knew that the ribosomes of the rough endoplasmic reticulum (RER) were the site of polypeptide synthesis. A proportion of these described glycosylation to form a glycoprotein, a greater number described this as occurring in the Golgi body than in the lumen of the RER; either location was credited. Many knew that the polypeptide (or protein) was transferred to the Golgi body and could have gained credit by adding that the transfer was in a transport vesicle. Some correctly suggested other post-translation modifications that could occur. The packaging of the glycoprotein into a Golgi vesicle was frequently described. It was not necessary to continue the response to describe the movement of the Golgi vesicle to the cell surface membrane.

(c) Most candidates gave a correct role for glycoproteins in the cell surface membrane.

BIOLOGY

Paper 9700/31
Advanced Practical Skills 31

Key messages

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

Candidates should be encouraged to record the results of their investigations in an appropriate table, even if the results obtained are not as expected. Subsequent questions should then be answered using actual results.

Candidates should be aware that the wording of questions is an important indicator as to how they should respond. The word 'explain' may imply reasoning or reference to theory, depending on the context. In **Question 1(b)(i)**, candidates needed to give reasons as to why something happens, in this case referring to the formation of more enzyme-substrate complexes between 20 mmol dm^{-3} and 40 mmol dm^{-3} of lactose and the active site of the enzyme being saturated between 60 mmol dm^{-3} and 100 mmol dm^{-3} of lactose.

When the question says 'state one significant source of error' or 'identify three observable differences' the candidate needs to select answers carefully and provide the appropriate number of responses rather than an extended list.

Candidates should be encouraged to observe fine detail when viewing slides under a microscope and include such detail when producing diagrams, such as the shape of the tissue layers and the section in plan diagrams and the relative sizes and shapes of xylem vessel elements in high power diagrams.

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.

It is important that candidates read the whole of each question before attempting it so that they are more able to plan their time carefully and answer the specific questions accurately.

Comments on specific questions

Question 1

(a) (i) The majority of candidates organised their results clearly by presenting a ruled table and including the heading for the independent variable, pH, and the heading for the dependent variable, time and seconds. Most candidates gained credit for recording the time for two beads in each pH to rise and the majority recorded results showing that the time for pH 3 was longer than the time for pH 7. Most candidates recorded the results as whole seconds.

(ii) The majority of candidates correctly stated pH as the independent variable.

(iii) The majority of candidates correctly stated one significant source of error in the investigation as the difficulty in judging when the bead reached the top of the solution or that the beads were not all the same size. Some candidates stated that the beads were not in the pH buffers for the same length of time and a few candidates stated that the beads touched the sides of the test-tubes.

(iv) The majority of candidates correctly recorded a time for **U** between pH 3 and pH 8 consistent with the results recorded in **Question 1(a)(i)**. A few candidates did not include the units.

(v) The majority of candidates used the results from **Question 1(a)(i)** and **Question 1(a)(iv)** to correctly estimate the pH of solution **U**.

(vi) Most candidates correctly described how to modify the procedure to investigate the effect of changing the concentration of the substrate on the time taken for the beads to rise. Most candidates correctly suggested using five different concentrations of hydrogen peroxide and some described producing the different concentrations by using serial or proportional dilution. Some responses incorrectly suggested using five different concentrations of yeast as the substrate. Many candidates correctly stated the pH should be kept the same.

(b)(i) Some candidates correctly stated that between 20 mmol dm^{-3} and 40 mmol dm^{-3} the concentration of lactose was the limiting factor and between 60 mmol dm^{-3} and 100 mmol dm^{-3} the enzyme was the limiting factor. Where the term 'limiting factor' was correctly explained in these responses, credit was awarded. However, the majority of candidates described the increase in the rate of reaction as the concentration of lactose increased between 20 mmol dm^{-3} and 40 mmol dm^{-3}, which gained no credit. Some candidates explained that the increase in the rate of reaction was because there was an increase in the number of lactose molecules so there were more successful collisions between lactose and the enzyme and therefore more enzyme-substrate complexes were formed. Some candidates described the rate of reaction reaching a plateau between 60 mmol dm^{-3} and 100 mmol dm^{-3}, which gained no credit. Many candidates correctly explained that the active sites of the enzymes were fully occupied but then stated that no more enzyme-substrate complexes could be formed or that the reaction had stopped so did not gain any credit.

(ii) Most candidates correctly showed how to estimate the Michaelis-Menten constant (K_m) of lactase on the graph and stated K_m as 18 mmol dm^{-3}. The most common error was to calculate K_m correctly showing the calculation instead of showing how the figures for V_{max} and ½ V_{max} were obtained on the graph.

(c) The majority of candidates used the headings given in the table to correctly label the *x*-axis (type of mammal) and the *y*-axis (concentration of lactose / mmol dm^{-3}). The majority of candidates also labelled each bar clearly and drew bars of equal width on the *x*-axis. Most candidates used a scale of 50 mmol dm^{-3} to 2 cm for the *y*-axis and plotted each bar accurately. Many candidates drew ruled lines for the bars so that the vertical lines joined with the horizontal lines precisely. The most common error was drawing bars that were joined and not separate.

Question 2

(a) (i) Credit was awarded to candidates whose drawings did not include any cells and used most of the space provided. The majority of candidates gained credit for carefully following the instructions and drawing the midrib of the leaf. Most candidates gained credit for drawing at least four layers of tissue and showing the correct shape of the midrib. The stronger responses showed the detail of the large layer of cells above the central vascular bundle in the midrib. Many candidates used a label line to correctly identify the lower epidermis.

(ii) Credit was awarded to candidates whose drawings were made using a sharp pencil to produce thin continuous lines, with no shading, which joined up precisely and used most of the space provided. Some candidates gained credit for carefully following the instructions to draw a group of one large and three small adjacent xylem vessel elements, with each xylem vessel element touching at least two of the other xylem vessel elements and with double lines representing the xylem vessel element walls. The stronger candidates drew one large oval xylem vessel element and three small xylem vessel elements with different shapes. Many candidates used a label line to identify the lumen of one xylem vessel element. The most common errors were drawing lines that did not meet up precisely and drawing four circles the same size for all of the xylem vessel elements.

(b) (i) The majority of candidates identified at least two differences between **Fig. 2.2** and **J1** using only observable differences. Most candidates stated that trichomes were present in **Fig. 2.2** but they were absent on **J1** and that **Fig. 2.2** was round while **J1** was long and the midrib was a 'V' shape. Some candidates stated that **Fig. 2.2** had sunken stomata whereas **J1** did not have sunken stomata.

(ii) The majority of candidates correctly stated two observable features of the leaf section in **Fig. 2.2** which help the plant to survive in dry conditions. For further credit, candidates also needed to explain how the stated features allow the plant to survive in dry conditions. For example, trichomes trap water vapour reducing the water potential gradient. The most common error was suggesting that trichomes were used to absorb water from the soil.

(c) Most candidates correctly measured the length of structure **X** and the scale bar with the appropriate units. The stronger candidates showed the division of the length of the scale bar by the actual length of the scale bar (430 µm) and then showed the length of structure **X** divided by the answer. Most candidates correctly recorded the actual diameter of structure **X** with the appropriate units. The most common error was not measuring the scale bar.

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Advanced Practical Skills 32

Key messages

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

When drawing a graph, a linear scale should be chosen which allows the data to be plotted to within half a 2 mm square.

Candidates should be encouraged to observe fine detail when viewing slides under a microscope and include such detail when producing diagrams, such as the shape of the tissue layers and the section in plan diagrams and the relative sizes and shapes of xylem vessel elements in high power diagrams.

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.

It is important that candidates read the whole of each question before attempting it so that they are more able to plan their time carefully and answer the specific questions accurately.

Comments on specific questions

Question 1

(a) (i) The majority of candidates were able to show a serial dilution of 8.0% reducing sugar, with the correct concentration below each beaker (4.0%, 2.0%, 1.0% and 0.5%) and showing the transfer of 10 cm^3 of the previous concentration to the next beaker then adding 10 cm^3 of distilled water to each beaker. A few candidates showed proportional dilution, so they had different volumes and concentrations below each beaker.

(ii) The majority of candidates organised their results clearly by presenting a ruled table and including the heading for percentage concentration of reducing sugar (**R**) and the heading for time and seconds. The majority of candidates gained credit for recording the time for all the concentrations of reducing sugar made and recording results which showed that the time for the highest concentration of reducing sugar was shorter than the time for the lowest concentration of reducing sugar. Credit was awarded to most of the candidates for recording the results as whole seconds.

(iii) Most candidates correctly identified one source of error in step 7 as the difficulty in identifying the first colour change.

(iv) The majority of candidates correctly stated a volume of grape extract **G** equal to or less than the volume of Benedict's solution used in the investigation to test for reducing sugars.

(v) Most candidates correctly recorded a time for the first colour change for **G** between 4.0% and 1.0%. The most common error was not including the units.

(vi) Most candidates correctly used the scale of 20 s to 2 cm for the *y*-axis or used a suitable scale so that the results of the investigation could be accurately plotted. Some candidates correctly used a scale of 2% to 2 cm for the *x*-axis. The most common error was using a non-linear scale for the *x*-axis, for example with the concentrations used placed evenly spaced along the *x*-axis. A few candidates correctly drew a line of best fit.

(vii) Most candidates used the time from **Question 1(a)(v)** to correctly estimate the percentage concentration of reducing sugars in **G** and showed how the concentration was estimated by drawing lines on the graph. The most common error was not showing on the graph how the percentage concentration of reducing sugars had been estimated.

(viii) Many candidates correctly described using a range of concentrations with narrower intervals, or stated concentrations, around the estimate for **G** and suggested repeating the whole experiment and calculating a mean. A few candidates suggested using a white background to see the colour change more clearly.

(b) (i) Many candidates used the headings given in the table to correctly label age of grapes / days on the *x*-axis and percentage concentration of reducing sugars on the *y*-axis. Most candidates plotted the points exactly, with a dot in a circle or a small cross.

(ii) Most candidates correctly used the estimate from **Question 1(a)(vii)** and the graph in **Question 1(b)(i)** to estimate the age of the grapes that were used to make grape extract **G**.

(c) Some candidates used the data in **Fig. 1.3** and **Fig. 1.4** to state that as the grapes aged the concentration of amylase and reducing sugars increased. Many candidates correctly explained that amylase is an enzyme which hydrolyses starch to reducing sugar. Some candidates suggested that an increase in amylase would mean that more starch was hydrolysed so more reducing sugars were produced and this would mean that as the grapes aged and the concentration of amylase increased, the concentration of reducing sugars would also increase. The most common error was to use only the data in **Fig. 1.4**.

Question 2

(a) (i) Credit was awarded to candidates whose drawings did not include any cells and used most of the space provided. The majority of candidates gained credit for carefully following the instructions and drawing the region of the root indicated in **Fig. 2.1**. The stronger candidates gained credit for drawing at least four layers of tissue and showing the correct shape of the outline of the section. Most candidates used a label line to correctly identify the endodermis.

(ii) Credit was awarded to candidates whose drawings were made using a sharp pencil to produce thin continuous lines, with no shading, which joined up precisely and used most of the space provided. Some candidates gained credit for carefully following the instructions to draw a group of four adjacent xylem vessel elements, with each xylem vessel element touching at least two of the other xylem vessel elements and with double lines representing the xylem vessel element walls. The stronger candidates drew a different shape for each xylem vessel element. Most candidates used a label line to identify the cell wall of one xylem vessel element. The most common errors were drawing lines that did not meet up precisely and drawing four circles the same size for all of the xylem vessel elements.

(b) (i) The majority of candidates identified at least two differences between **K1** and **Fig. 2.2**. using only observable differences. Most candidates stated that the outline of the section on **K1** was ‘wavy’ and round in **Fig. 2.2**, and that the size of the vascular tissue on **K1** was smaller than in **Fig. 2.2**. Some candidates stated that **K1** had a thicker endodermis than **Fig. 2.2**.

(ii) The majority of candidates correctly measured the scale bar and the diameter of the root in **Fig. 2.2** using the line **A–B** placed across the figure, with the appropriate units. Most candidates correctly calculated the actual diameter of the root and showed the appropriate units. The stronger responses showed all of the steps in the calculation, for example, 500 µm divided by the measurement of the scale bar and the answer multiplied by the measurement of line **A–B**. The most common error was not measuring the scale bar so the actual diameter of the root could not be calculated.

(iii) Many candidates gained credit for correctly calculating the magnification using the actual diameter of the root calculated in **Question 1(b)(ii)**.

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Paper 9700/33
Advanced Practical Skills 33

Key messages

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

When the question asks 'Identify the sources of error in the investigation', the candidate needs to evaluate what happened during the procedure that decreased the accuracy of observation or measurement, such as the passage of the drop of milk through the copper sulfate solution can be hindered by the drops of milk that are present from previous attempts.

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 should read the whole of each question first before attempting it; this should help them to plan their time carefully and answer the specific questions accurately.

Comments on specific question

Question 1

(a) (i) Many candidates correctly completed **Table 1.2** by stating three concentrations of milk (85%, 75% and 65%) and stating the correct volumes of **M** 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 percentage concentration of milk and the heading for time with units (seconds). The majority of candidates gained credit for recording a time for each of the five concentrations of milk. The stronger candidates recorded at least three times for each concentration of milk and recorded the times in whole seconds.

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

(iv) Most candidates correctly assessed the risk of this procedure as low since copper sulfate solution was rated as an irritant in **Table 1.1**.

(v) Some responses correctly stated that a significant source of error in the investigation was the difficulty of starting timing when the drop passed the line drawn at the top of the test-tube and that a correct improvement was to use a camera to record the exact moment this happened. Some correctly identified that the drops of milk were not all the same volume and the correct improvement would be to use a micropipette or a graduated pipette. Some candidates observed that the drop sometimes touched the side of the test-tube, slowing its descent, and the correct improvement would be to use a wider test-tube.

(b) (i) Most candidates used the headings given in **Table 1.4** to correctly label the *x*-axis (temperature / °C) and the *y*-axis (density of milk / au). Some candidates labelled the incorrect axis or gave incomplete headings. The stronger candidates, for the *x*-axis, used a scale of 5 to 2 cm and for the *y*-axis, used a scale of 4 or 5 to 2 cm with the origin labelled as 20. 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) Many candidates used the graph correctly to determine the density of milk at 23 °C.

(iii) Some candidates correctly explained that the hypothesis was supported when the temperature increased from 10 °C to 20 °C as the density of the milk decreased by 2 au. The stronger answers correctly stated that the hypothesis was not supported when the temperature increased from 20 °C to 30 °C as the density of the milk decreased by 7 au.

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 whole section on **L1**. Many gained credit for drawing at least two layers of tissue and drew two lines around the stele. The stronger responses showed subdivision of the stele and used a label line to correctly identify the cortex.

(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 four adjacent xylem vessel elements with each vessel element touching at least two others, with double lines representing the walls. The most common error was to draw lines that did not meet up precisely or were too thick. Many responses were credited for showing vessel elements which had at least five sides. Most used a label line to show the cell wall of one xylem vessel element.

(iii) Most candidates correctly described an observable feature to identify the cells on **L1** as xylem vessel elements by stating that they had thick walls or had a large lumen.

(b) (i) Many candidates listed three observable differences such as the epidermis on **L1** was thinner than in **Fig. 2.1** or that there were trichomes present on **L1** and none in **Fig. 2.1** or there were no stomata on **L1** but these were present in **Fig. 2.1**.

(ii) Many candidates correctly stated one observable similarity between the vascular bundle on **L1** and the vascular bundle in **Fig. 2.1**. The most common correct answers were that both had vascular bundles located in the centre or that both had vascular bundles surrounded by an endodermis.

(c) Most candidates accurately measured the length of the scale bar and the line **P**–**Q** correctly and stated the appropriate units. Some candidates showed the length of the scale bar divided by 150 to give a value for the magnification. The stronger candidates then showed the length of **P**–**Q** divided by the value for the magnification. Many candidates stated the correct answer and included appropriate units (µm).

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Paper 9700/34
Advanced Practical Skills 34

Key messages

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

Candidates should be aware that the wording of questions is an important indicator as to how they should respond. The word 'explain' may imply reasoning or reference to theory, depending on the context. It is another way of asking candidates to 'give reasons for'. In **Question 1(c)(iii)**, candidates needed to detail reasons as to why something happens between 0.1 mmol dm^{-3} and 0.2 mmol dm^{-3} of lactase, such as referring to the increased number of active sites available, more effective collisions and therefore more enzyme-substrate complexes forming.

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 should read the whole of each question first before attempting it; this should help them to plan their time carefully and answer the specific questions accurately.

Comments on specific questions

Question 1

(a) (i) Many candidates were able to show a serial dilution of 5.0% protein, with the correct concentration below each beaker (2.5%, 1.25%, 0.625% and 0.3125%) and showing the transfer of 10 cm^3 of the previous concentration to the next beaker then 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 protein and the heading for colour. Most candidates gained credit for recording a colour for each of the five concentrations of protein solution. Most recorded the colour for the highest concentration as purple and the colour for the lowest concentration as blue.

(iii) Most candidates correctly stated the colour for sample **U** as purple.

(iv) Many candidates used their results to correctly estimate the protein concentration in **U**.

(v) Some candidates correctly stated that a significant source of error in the investigation was the difficulty of identifying the colour of the protein solution and the improvement was to use a colorimeter.

(vi) Some responses correctly suggested that to modify the experiment to determine the concentration of reducing sugars in a sample of milk, Benedict's solution should be added to the milk, it should be heated to at least 80°C and the time recorded to the first colour change. The stronger candidates went on to suggest carrying out this test for known concentrations of reducing sugars and comparing these results with the result for the sample of milk.

(b) Most candidates correctly used the headings given in **Table 1.2** to correctly label the *x*-axis (type of milk) and the *y*-axis (protein content / g per 100 cm^3). Some labelled the incorrect axis or gave incomplete headings. Most candidates drew the bars separated and of equal width and distance apart on the *x*-axis, used a scale of 0.5 to 2 cm, labelled at least every 2 cm and plotted each bar accurately. The stronger candidates drew ruled lines for the bars so that the vertical lines joined with the horizontal lines precisely. The most common error was drawing lines which were not ruled.

(c) (i) Most candidates used the graph in **Fig. 1.4** to determine the mass of lactose converted when 0.16 mmol dm^{-3} of lactase was used by drawing a line from the *x*-axis at 0.16 mmol dm^{-3} and stating the mass of lactose as 54.

(ii) Many candidates correctly calculated the rate of lactose conversion when 0.16 mmol dm^{-3} of lactase was used as 5.4 g min^{-1}.

(iii) Some responses correctly stated that there were more active sites available between 0.1 mmol dm^{-3} and 0.2 mmol dm^{-3} of lactase. Many went on to explain that there were more successful collisions and more enzyme-substrate complexes forming for further credit.

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 of the stem on **N1** indicated by the shaded area in **Fig. 2.1**. Many candidates gained credit for drawing a minimum number of vascular bundles and the epidermis as two lines. The higher-achieving responses showed the stem becoming smaller at one end, subdivision of the vascular bundles and used a label line to correctly identify the xylem in one vascular bundle.

(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 were able to draw four adjacent cells with each cell touching at least two of the other cells, with double lines representing the walls. The most common error was to draw lines that did not meet up precisely or were too thick. Many candidates were credited for showing cells which had at least five sides. Most candidates used a label line to show the cell wall of one cell.

(b) Many candidates listed three observable differences, such as the epidermis on **N1** was thinner than in **Fig. 2.2**, there were no trichomes present on **N1** but present in **Fig. 2.2** or there was no endodermis on **N1** but endodermis was present in **Fig. 2.2**.

(c) (i) Many candidates correctly stated that there were 40 eyepiece graticule units within one division of the stage micrometer (0.50 mm). The stronger candidates then showed 0.50 divided by 40 to calculate the actual length of one eyepiece graticule unit and stated the correct answer (12.5) with the appropriate units (µm).

(ii) Many candidates correctly stated that the length of the trichome was between 30 and 40 eyepiece graticule units in length. The stronger candidates multiplied this number by the actual length of one eyepiece graticule unit calculated in **Question 2(c)(i)** and gave the correct answer with the appropriate units (µm).

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Paper 9700/35
Advanced Practical Skills 35

Key messages

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

When the question asks 'Identify a source of error in the investigation', the candidate needs to evaluate what happened during the procedure that decreased the accuracy of observation or measurement, such as that the discs of potato were not all of the same thickness so this would affect the outcome of the investigation.

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 should read the whole of each question first before attempting it; this should help them to plan their time carefully and answer the specific questions accurately.

Comments on specific questions

Question 1

(a) (i) Many candidates correctly completed **Table 1.2** by stating three concentrations of salt solution (0.75, 0.5 and 0.25 mol dm^{-3}) and stating the correct volumes of **S** 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 concentration of salt / mol dm^{-3}. Some included the heading for length at the beginning and the heading for length at the end with units (mm). The stronger candidates included another heading for change in length with units (mm). Many candidates gained credit for recording a length for each of the five concentrations of salt solution. The higher-achieving candidates also recorded the change in length for each of the concentrations of salt solution. The results of most candidates showed that the potato discs in the lowest concentrations of salt solution showed the greatest increase in length.

(iii) Many candidates correctly explained their results for the 0.0 mol dm^{-3} salt solution by stating that the water potential of the potato tissue was lower than the water potential of the salt solution so water moved into the potato by osmosis.

(iv) Many candidates correctly suggested that the reason why a line of 10 discs was measured instead of a single disc was that a more accurate measurement was possible for 10 discs that was not possible when measuring a single disc.

(v) Some candidates correctly stated that a significant source of error in the investigation was that the potato discs were left in the salt solutions for different times or that not all the discs were 3 mm in thickness.

(vi) Many responses correctly estimated the salt concentration where there was no net movement of water into or out of the potato by stating the concentration at which there was no change in length of the potato disc.

(vii) Some candidates correctly described improvements to the procedure that would make the estimate in **Question 1(a)(vi)** more accurate by stating the use of smaller intervals of salt concentrations around the estimate or repeating the procedure and calculating the mean.

(b) (i) Most candidates correctly used the headings given in **Table 1.3** to label the *x*-axis (food type) and the *y*-axis (salt content of unprocessed food / mg per 100 g food). Some candidates labelled the incorrect axis or gave incomplete headings. Most candidates drew the bars separated and of equal width, used a scale of 20 or 25 to 2 cm with the origin labelled as 0 for the *y*-axis and plotted each bar accurately. The stronger candidates drew ruled lines for the bars so that the vertical lines joined with the horizontal lines precisely. The most common error was drawing lines which were not ruled.

(ii) Many candidates correctly calculated the percentage increase in salt content when salmon was processed by showing 1800 minus 95 divided by 95 and multiplied by 100. The stronger candidates expressed their answer to two significant figures and stated 1800.

(iii) Many candidates correctly stated the independent variable as food type or processed and unprocessed food.

Question 2

(a) (i) Credit was awarded to candidates whose drawings did not include any cells and used most of the space provided. The higher-achieving candidates gained credit for carefully following the instructions and drawing the region of the leaf indicated by the shaded region in **Fig. 2.1**. Many candidates gained credit for drawing at least three layers of tissue and drew the midrib as V-shaped. The most successful answers showed one large vascular bundle in the midrib below a distinct area of cells. Many candidates used a label line 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 four adjacent xylem vessel elements with each vessel element touching at least two others and with double lines representing the walls. The most common error was to draw lines that did not meet up precisely or were too thick. Many candidates were credited for showing xylem vessel elements which had at least five sides. Most candidates used a label line to show the wall of one xylem vessel element.

(b) (i) Many candidates stated that there were 19 eyepiece graticule units within one division of the stage micrometer (1 mm). The stronger candidates then showed one divided by 19 to calculate the actual length of one eyepiece graticule unit and stated the correct answer with the appropriate units (μm).

(ii) Many candidates correctly stated that there were 38 eyepiece graticule units across the leaf depth. The stronger candidates multiplied 38 by the actual length of one eyepiece graticule unit calculated in **Question 2(b)(i)** and gave the answer to two significant figures with the appropriate units.

(iii) Many correctly suggested that a function of the air spaces was related to gases in the leaf or contributing to the buoyancy of the leaf.

(iv) Many candidates listed three correct observable differences, such as the epidermis on **M1** was thicker than in **Fig. 2.3** or that there were fewer vascular bundles present on **M1** and more vascular bundles in **Fig. 2.3** or there were many stomata on **M1** but these were absent in **Fig. 2.3**.

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Paper 9700/41
A Level Structured Questions 41

Key messages

There was much evidence of thorough learning of facts, lists and model answers and credit was achieved where this approach was appropriate. In other instances, a more selective and context-specific approach was required, so that genuine understanding could be revealed rather than a rigid body of knowledge.

General comments

Candidates performed well on this paper, particularly those who were both well prepared in terms of syllabus knowledge and well-practised in the skills of reading question context material, tables and graphs, and selecting relevant information for their answer. Candidates displayed a good breadth of knowledge and often used subject-specific terminology accurately. Weaker answers confused terms relating to meiosis (e.g. chromosome, chromatid, bivalent) and neurone function (resting, receptor, threshold and action potentials). The topic areas where candidates performed best were photosynthesis, kidney physiology, genetics, meiosis and respiration. Candidates found **Question 10** to be the most difficult question on the paper, since it needed candidates to integrate knowledge from two different areas of the syllabus and to explain a negative situation (absence of active gibberellin).

Comments on specific questions

Question 1

(a) Candidates were asked to link structures labelled on a transmission electron micrograph of a chloroplast to the functions carried out by these structures. Candidates did this task well. The most well-known facts were that triose phosphate is made in the stroma and that some chloroplast proteins are synthesised on stromal ribosomes. Some candidates confused structure **B**, the thylakoid space, with structure **C**, the thylakoid membrane, when deciding what pumps protons and where protons accumulate.

(b) (i) Most candidates were able to describe part of the method required to separate pigments using chromatography. Well-known steps were the need to place the chloroplast membrane extract onto a pencil baseline and to ensure that the baseline of the chromatogram was above the solvent level. Less well-known was the need to draw a line near the top so that when the solvent front reaches this the chromatogram can be removed from the solvent. Candidates did less well on the second part of the question, on how to identify the pigments. Many gave the formula to calculate an R_f value but few stated that the experimental R_f values would be compared with published values for the purpose of naming or identifying the pigments.

(ii) Most answers explained that the purpose of the different pigments was to absorb different wavelengths of light. Strong answers stated that this would increase the rate of photosynthesis. Some candidates named two or more thylakoid membrane pigments.

Question 2

(a) (i) Few candidates could clearly define the term ecosystem. Points missing from answers were that an ecosystem comprises all the different organisms, that is, the entire community of organisms plus their interactions with each other (the biotic component), plus their interactions with the abiotic component of the environment. Common errors included referring to ‘abiotic organisms’ and ‘nonliving organisms'. Some answers included many correct terms and these needed to be linked in a meaningful way to answer the question.

(ii) Most candidates could define the term niche as the role of a species in its ecosystem.

(b) (i) Many answers referred to the systematic approach to sampling instead of naming the technique described.

(ii) Stronger candidates organised their answers clearly to show which levels of biodiversity were assessed and which were not. Some candidates were not familiar with the three levels of biodiversity listed on the syllabus. Each beach area sampled between the tide marks was assessed as a single entity so the method described did not assess habitat diversity.

(c) (i) Most candidates identified an organism that had increased in abundance on the table and gave as their answer the first, genus, name of that organism, as requested. Incorrect answers added the species name or gave the English name instead of the Latin genus.

(ii) From the information given in the question around half of the candidates selected from the general features of the Protoctista the ones that applied to seaweeds. A few candidates confused Protoctista with Prokaryota. Many answers gave contradictory statements, such as seaweeds being both autotrophic and heterotrophic.

(d) This was a challenging question for many candidates as it required them to explain the effects of the removal of rats rather than just the effects of their presence. Candidates needed to explain how removing rats affected the other species in the food chain, not just quote numbers from one or both tables without suggesting logical reasons for the changes shown. Strong candidates compared the two tables and realised that the similarities in the figures showed that removing rats had returned the balance of species to the situation seen on an island that has never housed rats. The commonest correct point seen was that rats were an alien or an invasive species.

Question 3

(a) (i) Many candidates were able to state that aerenchyma tissue allows oxygen transfer to the submerged roots of the rice to allow aerobic respiration to occur. Some weaker candidates focused on a supposed need to transfer carbon dioxide to the roots for photosynthesis.

(ii) Candidates mostly understood that submerged roots in rice plants respire in anaerobic conditions and are adapted to tolerate the high concentrations of ethanol produced.

(iii) Answers needed to clearly explain the step-wise progress of a selective breeding programme to produce rice plants with fast-growing stems, which involves selecting and crossing the best offspring as well as the best original parents, and continuing to carry out both selection and crossing in each generation for several generations. Some candidates suggested cross-breeding seeds rather than plants or rice individuals.

(iv) Well-prepared candidates described the role of auxins in stem elongation in detail, particularly protons pumps moving protons from the cytoplasm to the cell wall, and the passage of water into cells by osmosis causing the cells to expand and the stem overall to increase in length. The biochemical details of the effect of acidity on the cellulose cell wall were described vaguely by some, using the words 'loosening' and 'weakening' rather than referring to hydrogen bonds between cellulose molecules or microfibrils breaking.

(b) Many candidates commented that the different rice species experienced different selection pressures and that although they were not geographically separated, they were ecologically separated. Some candidates knew the term seasonal or temporal isolation, although many candidates incorrectly referred to the different flowering times as 'behavioural isolation', which is a term reserved for animals. Almost all candidates explained in various wordings that the two species became reproductively isolated. A few suggested polyploidy might be a factor in sympatric speciation.

Question 4

(a) (i) The term recombinant DNA was well-known although some candidates struggled to give a full definition. Candidates recognised that this involved more than one organism, source or species. Those who also went on to state that it was DNA from these organisms or that the different pieces of DNA are attached to each other, were awarded further credit.

(ii) The advantages of recombinant rather than animal-derived insulin were well-known, with large scale production, the absence of ethical and religious issues and no immune response being the commonest correct answers. The answer seen least often was that human insulin gives a faster response, with some answers stating it was more effective without saying in what way.

(b) (i) To arrive at the correct answer, cow, candidates needed to compare the amino acid sequences in the table and select the one that most closely matched that of cats. Weak answers named an amino acid or amino acid position instead of a type of insulin.

(ii) Strong candidates realised that the normal gene sequence needed to be edited to create a genetic blueprint for an altered, analogue insulin molecule, and some used **Table 4.1** to pinpoint the changes in the amino acid sequence required. Others suggested synthesising the desired nucleotide sequence de novo. Many candidates described obtaining a normal human insulin gene and creating transgenic bacteria containing this, which did not answer the question of how to produce an analogue insulin. These candidates needed to more carefully read the introduction to the question which explained what an analogue insulin molecule is. The weakest candidates simply wrote down what they knew about the technical term 'genetic engineering' rather than engage with the context of the question asked.

(c) Many candidates gave rehearsed answers about databases in general without engaging with this precise question. The commonest correct answer was the speed advantage of having sequence data readily available, although few stated that databases can be accessed online. Many answers correctly stated that databases can be used to find sequences and then to compare them, and that closer similarity between sequences indicates a closer evolutionary relationship.

Question 5

(a) (i) The labels glomerulus and Bowman's capsule were mostly well-known, although sometimes given the wrong way round.

(ii) The build-up of high pressure in the glomerulus was carefully explained in many responses and the term 'ultrafiltration' was occasionally seen. Some candidates mistakenly argued that substances moved due to diffusion or osmosis, whereas in fact movement occurs due to the pressure gradient. This affects all components of the blood, with the only restriction to movement being the physical or electrostatic blocking effect of the combined capillary endothelium pores, basement membrane and slit pores. Candidates knew that small molecules passed through something and large proteins did not pass through but often did not state where the molecules came from or were going to. Some answers described blood cells as large molecules.

(b) (i) Adenyl cyclase and cAMP were both well-known. An occasional error was to suggest 'acetyl cyclase' for the enzyme.

(ii) This was a challenging question, with both the description and explanation parts of the task presenting difficulties for weaker candidates. The general relationship between the *x* and *y* parameters was not always stated correctly or stated to apply to both normal people and people with C SIAD. Figures quotes were not always relevant comparisons or exact (on this graph a ruler was useful to read axis values for points accurately). A common error was for candidates to assume the *x*-axis was time and to state that 'In C SIAD ADH concentration increased earlier', instead of at a lower sodium ion concentration. Candidates who thought that the maximum ADH concentration was the most important difference argued the opposite of the true position, which is that the higher ADH concentration in the blood at lower sodium ion concentrations in C SIAD leads to increased permeability and reabsorption of water at the collecting duct. Stronger answers reasoned that for this reason the urine would be more concentrated in C SIAD people and that their blood would have high water potential or a low sodium ion concentration.

Question 6

(a) (i) Many candidates worked out the correct genotypes. The most common error was writing the superscript ‘h’ as ‘H’.

(ii) Candidates seemed unfamiliar with the concept of ‘breeding true’, although many worked out that it must be the homozygous recessive phenotype, and correctly described this phenotype (albino long) in their answer. A few candidates gave a genotype instead of a phenotype.

(b) Candidates who read the question carefully and who were practised in setting out all the stages of a genetic cross in a series of logical steps gained full credit. Some candidates started with the genotypes for the original cross instead of with the F1 individuals who were crossed. A common omission was to fill in genotypes in a Punnett square without then showing their phenotypes. This can be done using initials, colours or symbols linked to a key to save time and space, but the phenotype for every genotype in the Punnett square should be shown. Similarly, the final ratio should show the number of each phenotype, not just the numbers alone.

(c) (i) Stronger candidates attempted to answer the specific question about why in this case the two genes assort independently, with the commonest correct answers being that the genes are on separate chromosomes and that they assort independently to give different allele combinations in the gametes. Candidates struggled to describe what exactly it is that orients itself on the equator at metaphase I of meiosis (pairs of homologous chromosomes) and that this orientation is independent of other homologous pairs of chromosomes. Some weaker candidates wrote out a list of all factors that contribute to genetic variation, including aspects irrelevant to this question such as crossing over and random mating.

(ii) Candidates were asked to supply expected numbers in the chi-squared table. Some candidates did not provide an answer and others worked back from the numbers given in the fourth column and made mistakes. The correct approach was to find the observed total from column 1 (48) and then to divide this according to the expected ratio of 9:3:3:1, i.e. 48 divided by 16 gives 3, then to multiply 9, 3, 3 and 1, each by 3.

(iii) Most added the figures in column 4 correctly and gave their answer to the same number of decimal places as seen in that column of the table.

Question 7

(a) A large proportion of candidates realised that serine and pyruvate both have three carbon atoms and that asparagine and oxaloacetate both have four carbon atoms. They were able to apply their knowledge of the molecules in the link reaction and the Krebs cycle to new information about amino acids.

(b) (i) The majority scored credit for identifying the different ions entering the post-synaptic neurones at glycinergic and cholinergic synapses. Most candidates recalled that acetylcholine is the neurotransmitter that operates in cholinergic synapses; relatively few spotted the difference that acetylcholine is broken down in the synaptic cleft while glycine is not.

(ii) Strong candidates realised that a hyperpolarised neurone was less likely to reach threshold potential when sodium ions entered. Many candidates had difficulty using the correct terms membrane potential or resting potential to describe what it was that became more negative when chloride ions entered the post-synaptic neurone. Weaker candidates just reasoned that negative ions do not cause an action potential. A few candidates mistakenly referred to ‘receptor potential’ or ‘action potential’ instead of threshold potential.

(iii) This question was answered well by most candidates. Many recalled that sodium-potassium pumps use active transport to move three sodium ions out of the neurone for every two potassium ions moved in. Fewer candidates included the ideas of a difference in membrane permeability to the two ions and greater negative charge inside the neurone. Common errors included: the ions moving in the wrong directions, an incorrect number of ions, ‘sodium and potassium’ rather than ‘sodium ions and potassium ions’, and ions moving ‘into’ rather than ‘across’ the membrane.

Question 8

This question was well answered. The majority of candidates identified that chromosomes had condensed and that crossing over has occurred in the locust testis cell at late prophase I of meiosis. Common mistakes included confusing chromosomes and chromatids, and sister and non-sister, and misusing the terms bivalent and synapsis. Few candidates pointed out that the chiasmata visible in the micrograph show where crossing over has previously occurred.

Question 9

(a) The majority of candidates realised that PC deficiency is not influenced by environmental factors. A smaller number of candidates stated that the distribution of PC deficiency in a population shows discontinuous variation. The commonest wrong answer for the second gap was ‘genetic’.

(b) A few candidates did not name any specific coenzymes. A proportion of candidates focused solely on NAD and FAD without mentioning coenzyme A. Common errors and omissions included: stating that NAD or FAD act as enzymes to directly dehydrogenate intermediates (rather than that they assist dehydrogenase enzymes), stating that NAD or FAD carry electrons or protons alone rather than hydrogen (or $e^- + H^+$), and suggesting that FAD is involved in glycolysis and the link reaction. Some candidates were unable to name coenzyme A in full and some wrongly stated ‘the enzyme coA’.

Question 10

Only the strongest responses gained more than half of the credit available for this question. Many candidates gave their answer in terms of the positive effects of the dominant allele rather than the reduced stem growth of a plant that is homozygous recessive, as required by the question. A large number of candidates described the effect of gibberellin on seed germination rather than on stem elongation. A common misconception was that ***le*** codes for the production of inactive gibberellin, rather than the idea that inactive gibberellin does not get acted upon by an enzyme to make active gibberellin. Several candidates thought gibberellin (rather than an enzyme) was the protein product of the ***Le*** gene. Strong candidates knew that a lack of active gibberellin prevents DELLA from being broken down, which stops PIF binding to a promoter. Many of the other details in the process, such as the lack of binding of GA to a receptor and the non-expression of growth genes, tended to be omitted or confused. Many candidates focused on the gene for amylase not being switched on, but this relates to the gibberellin signalling pathway in a germinating seed, not in a stem.

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A Level Structured Questions 42

Key messages

- Candidates should be precise with their answers. For example, in **Question 9(b)(i)**, credit was lost if cell membrane was stated instead of the term cell surface membrane or in **Question 7b**, depolarisation instead of depolarisation of the membrane.

- When candidates are asked to describe that a substance is moving, they should always state where the substance is moving from, where it is moving to and by which process it is moving, e.g. by simple diffusion, facilitated diffusion, active transport or co-transport. This was particularly important for **Question 6c**.

General comments

The paper was both accessible and discriminatory with many candidates scoring well. It allowed candidates to convey knowledge, articulate ideas and effectively analyse data. Novel contexts in questions did not cause difficulty for able candidates.

Comments on specific questions

Question 1

(a) (i) Most candidates appreciated that phosphorylation of glucose at the beginning of glycolysis was necessary to increase its energy level and make it more reactive, or to maintain its concentration within the cell by preventing its diffusion across the membrane. Some candidates, however, simply described what was shown in **Fig. 1.1**, stating that this is done so that it can be converted to fructose 1, 6-bisphosphate.

(ii) The role of reduced NAD as a hydrogen acceptor or carrier was well understood, with candidates providing detail as to how the hydrogen atom would be split at the inner mitochondrial membrane to provide hydrogen ions for chemiosmosis and electrons for the electron transport chain. A small number of candidates referred to the carriage of hydrogen ions, or electrons, alone. Few mentioned the function of reduced NAD in the reduction of ethanal or pyruvate, or its use in redox reactions.

(iii) The majority of candidates named substrate-linked (or substrate level) phosphorylation as the mechanism by which ATP is made in glycolysis, although there were a few references to oxidative phosphorylation.

(b) Most candidates were able to describe at least one condition necessary for pyruvate to enter the mitochondrion by active transport, most notably the requirement for ATP for the movement of pyruvate against its concentration gradient. Many also commented that oxygen should be available as without it Krebs' cycle and oxidative phosphorylation would not be able to proceed. The use of a carrier protein was rarely mentioned, as was the impermeability of the inner mitochondrial membrane. Some made the mistake of describing the carrier protein as a channel, or stating that active transport would be down a concentration gradient.

(c) This question was answered well by candidates across the full range of ability. Most stated that pyruvate would be decarboxylated and dehydrogenated to form an acetyl group that would react with coenzyme A to form acetyl coenzyme A. Many also added that the hydrogen atom removed would be transferred to NAD, forming reduced NAD, and that carbon dioxide would be released. Few errors were seen in answers to this question, although some candidates referred to the reduction of NADP.

Question 2

(a) Many candidates did not identify haploid and diploid as meaning one set and two sets of chromosomes. Most responses gave only a comparative formula, such as n and 2n, with haploid being most often described as having ‘half’ a full set. A significant minority gave their answers in terms of haploid having 23 chromosomes, and diploid 46, whereas this was a question asking about all organisms rather than specifically humans. Some did not refer to chromosomes in their answer but instead referred to ‘gametes’.

(b) Most candidates gained the majority of the credit available here. Prophase I was very well answered; most candidates correctly identified developments during this phase, either due to condensing chromosomes/chromatin, bivalent formation or crossing over. Many could have improved their responses for metaphase I by stating that it was the bivalents or homologous chromosomes lining up on the equator. Most were able to identify developments in anaphase I correctly. Telophase I was the poorest answered, as candidates wrote in terms of daughter cells or nuclear membrane reformation instead of the behaviour of chromosomes as required by the question. Candidates who gained credit for telophase I acknowledged the fact that chromosomes had reached the poles/ends of the cell. Weaker candidates confused chromatids with chromosomes.

(c) Most had no problem in identifying cytokinesis as the correct answer, although spelling mistakes were common. A minority referred to mitosis or reduction division.

Question 3

(a) (i) Most candidates correctly identified discontinuous as the type of variation in the fruit-wing characteristic of the sea blush plant. Incorrect answers included phenotypic or genetic variation.

(ii) The majority of candidates gained credit for stating that a new fruit colour could arise due to a mutation. Few mentioned a change in the environment or cross pollination. More able candidates referred to some alleles being codominant and therefore giving rise to a new colour.

(iii) Many candidates correctly stated that organisms of the same species would be able to breed together to produce fertile offspring and that they would have the same morphology. Some noted that the DNA sequence would be the same; others mentioned DNA and needed to add ‘sequence’ to gain credit for this idea. Occupying the same niche was rarely seen.

(b) Most candidates recognised that natural selection may occur due to mutations and selection pressures; some then contradicted themselves by stating that it happens as a result of exposure to selection pressure. The fact that populations can produce many offspring or that genetic variation occurs was rarely mentioned. Many candidates noted that individuals with advantageous alleles would survive or reproduce, but a common error was to state that the alleles themselves were selected or survived. There were many references to an eventual change in allele frequency rather than an increase.

Question 4

(a) Many candidates correctly named the two domains that are a source of restriction endonucleases and spelled them correctly. Weaker candidates struggled to recall the correct domain names of the prokaryotic cells that were required. Many gave the names of Kingdoms. Common incorrect answers were: Eukarya, Prokaryote, Eukaryote, Protoctista, Animalia, Fungi and viruses.

(b) Most candidates performed well in this question, often gaining full credit. Of those who did not gain full credit, where the gene would be extracted from, either from the DNA or the genome of bacteria, was found to be the most difficult. Some candidates chose the different method of obtaining mRNA for the required gene but again did not state where the mRNA came from. Some candidates incorrectly wrote that mRNA is converted into DNA instead of the idea that mRNA is used as a template to make cDNA. A minority of candidates clearly expressed the third method of obtaining the gene by synthesising it from nucleotides. Candidates who were able to use the syllabus learning outcome terminology with confidence did well in this question.

Stronger candidates clearly identified that PCR would be used to make more copies of the gene. Most recognised that a plasmid would need to be cut by a restriction enzyme to give sticky ends which would anneal to the gene by the action of ligase. Weaker candidates struggled to clearly express these points or were too vague with terms like vector instead of plasmid. A small number of candidates knew some extra detail of this process, for instance that complementary sticky ends would anneal or that ligase made phosphodiester bonds. Some weaker candidates suggested that *E. coli* was the vector. Some responses used the terms gene and enzyme interchangeably, for example when referring to the restriction enzyme being inserted into the plasmid. They did not distinguish between the enzyme and the gene coding for it.

The majority of candidates knew to add the recombinant plasmid to the bacteria. A significant number of answers gave some extra detail for this process, for instance the use of heat shock and calcium ions or electroporation. Some weaker candidates wrote that the gene would be inserted directly into the bacteria.

A small number of candidates were able to express the use of marker genes to identify bacteria that had been transformed with recombinant plasmids. Often, statements were too vague and did not mention that the selected bacteria would have the recombinant plasmid. Some suggested that it was the gene itself that fluoresced to indicate transformation, or that the DNA was tagged with fluorescence.

A large number of candidates knew that bacteria would be cultured and many knew the term fermenter. A small number of candidates finished their answer explaining that the enzyme would need to be extracted or purified.

A small number of candidates incorrectly based their whole answer on PCR describing all the steps of PCR.

(c) Most candidates found this question challenging and few responses achieved full credit. Most answers were not clearly expressed. Candidates were often able to explain that the database contained information about the DNA or structure relating to restriction enzymes, and needed to go on to explain that it held the base/amino acid sequences, and in large amounts. Where responses gained credit, it was often for the fact that the data could be accessed quickly or that it was easy to share. The term ‘efficiency’ was often used but not always explicitly the idea that the database makes the process faster. A minority of candidates explained that the sequences could be compared or used to model the structure of the enzyme with the aim of identifying the restriction enzyme to use. More general terms were often used rather than specific statements about base sequences. Some responses suggested a misconception that the database was full of actual restriction enzymes that could be removed and used, rather than information about their base sequences.

(d) The most successful responses were set out in a clear, structured style, often starting with the similarities and then moving on to the differences. Putting the differences in a table was often very helpful to the candidate as it was clear that a direct comparison had been made. Many candidates were able to make the point that both are techniques that separate substances or involve the movement of substances. Many understood that solubility and charge or mass separated the molecules. More able candidates referred to R_f values and an appropriate identification method for electrophoresis.

The main difficultly that limited the credit awarded was where detail was given for one of the techniques andt this was not matched with the difference in the detail for the other technique. For instance, no credit was awarded for statements such as ‘electrophoresis uses current but chromatography does not’. This was most evident when a candidate set out their answer as a separate list for each technique, often resulting in only one half of the difference described.

There were many vague answers and descriptions. General terms like ‘substances’ were not sufficient when comparing the type of molecule separated. Some answers incorrectly stated that both techniques could separate DNA, or that electrophoresis separated genes, not DNA.

Question 5

(a) (i) Stronger candidates were clear in their working in this question and gained full credit. The majority of candidates found this challenging and there were many candidates who did not attempt this question. The most common error was mistaking warfarin resistance as being caused by a recessive allele. Many stated that $p^2 = 0.4$, not allowing for homozygous and heterozygous individuals showing the dominant trait. Some who knew they needed to find q first did not realise that 0.6 would be q^2 and therefore arrived at the wrong answer. A significant number of responses found a value for $2pq$ and then halved it, not realising that $2pq$ is the frequency of heterozygotes in the population. Other common errors were to state that $q = 0.6$ or that 0.4 must be q or p.

(ii) Overall, this was well answered with many candidates correctly interpreting the question and gaining full credit. There was a wide range of acceptable marking points, the most common of which related to migration, large population and random mating. A significant number of responses missed out on full credit by stating three points rather than four as guided by the mark allocation. Very few responses commented on rats being diploid because they had heterozygous alleles. Some candidates confused the conditions for Hardy-Weinberg with those of the mark-release-recapture technique.

(b) This question focused on a scenario of an advantageous allele occurring and why its frequency would increase more quickly if it were a dominant allele rather than a recessive allele. Candidates did not relate that a new allele would arise as a single allele and therefore be found in a heterozygote. A majority gained credit for understanding that if the allele was a dominant allele, it would always be expressed in the heterozygote, and if it was a recessive allele, it would not be expressed in the heterozygote. Very few linked these ideas to the fact that selection can only act when the phenotype is present and therefore will act sooner on an individual with the dominant allele where the feature is seen in the phenotype as soon as the allele arises. Some candidates discussed how to obtain a homozygous recessive organism by crossing two heterozygotes, so had the idea that it was less likely to obtain a homozygous recessive in the offspring, but did not take this idea further. Many candidates mistakenly thought that the recessive allele would be disadvantageous or weaker.

Question 6

(a) Many candidates were unable to correctly label where the glomerular filtrate and blood plasma were located. A few placed the letters **F** and **P** on the image rather than using label lines as instructed.

(b) (i) Many candidates gained credit for the calculation but missed out on full credit as the units were incorrect or were omitted.

(ii) Candidates were asked to suggest and explain factors that would affect GFR. Most responses were limited in the credit they could achieve as they listed factors that could affect GFR rather than how the factors affect GFR. The most common correct responses were an increase in blood pressure causing an increase in GFR, an increase in hydration causing an increase in GFR and kidney disease leading to a reduction in GFR.

(c) Candidates who had learnt the details of the process of selective reabsorption were able to recall the events in sequence and scored well. Some could have improved by including details such as the sodium ions being pumped out of the cells or that they would return to the cells from the lumen or filtrate. Cotransport of glucose was mentioned frequently as was its eventual reabsorption into the blood. Many mistakenly stated that the water potential of the blood decreases rather than that of the cells. Some included details of how the PCT cells are adapted for selective reabsorption, which was not required in this question and so could gain no credit.

Question 7

(a) Many candidates found it difficult to suggest reasons why a reduction in temperature would decrease the efficiency of contraction of striated muscle cells: although candidates clearly understood the sliding filament theory, many were unable to adapt their knowledge to satisfy the requirements of the question. Consequently, there were several accounts of the mechanism of muscle contraction which gained no credit.

The most frequent response was to comment on the effect a lower temperature would have on enzyme activity, often explained in terms of fewer collisions and enzyme-substrate complexes, with reference to ATPase on the myosin head, acetylcholinesterase at the neuromuscular junction, or even ATP synthase in synthesis of ATP. Many also appreciated that a reduction in temperature would reduce the kinetic energy of molecules and ions, going on to state that acetylcholine might diffuse, or be released, more slowly or that the movement of calcium ions out of the sarcoplasmic reticulum would be retarded. Some then stated that fewer calcium ions would bind to troponin, resulting in fewer cross bridges between the myosin head and actin, and fewer power strokes. A minority of candidates went on to explain how events following the power stroke would be affected, usually a comment on reduced ATPase activity or slower ATP hydrolysis. Nevertheless, many candidates understood that the rate of respiration would decrease and that less ATP would be available for muscle contraction.

Some candidates mentioned that blood flow to muscles would decrease or that shivering would help to increase body temperature, and there were a small number of correct references to thermogenesis. A minority of candidates misread the question and described the effects of increased temperature.

(b) The effect of tetrodotoxin (TTX) on the functioning of a motor neurone was generally well understood. Most candidates began by stating that a change in the tertiary structure would prevent the voltage-gated sodium ion channels from opening so there would be no entry of sodium ions into the axon. However, while most realised that in the absence of sodium ions, depolarisation could not take place, few responses mentioned the membrane so were not credited. Most appreciated that an action potential would not be generated or that impulses would not be transmitted.

Fewer candidates described the possible effects at the neuromuscular junction. These most commonly stated that there would be no release of neurotransmitter, and there were also some references to vesicles not moving towards or fusing with the presynaptic membrane. A few candidates referred to muscle paralysis or failure of the muscle to contract; most gave vague statements about the effector not being able to respond. No descriptions of the consequences of TTX causing the sodium ion channels to remain open were seen.

Question 8

(a) (i) Most candidates stated that the rate of activity of GM rice was greater than non-GM rice or that the rate of activity increased in both, and a small number of candidates stated both points. Some missed out on credit for figures from the graph because they gave a value for GM rice at one concentration of carbon dioxide and a value for non-GM rice at a different concentration. Good explanations for the levelling off of the curve for non-GM rice were frequently given, such as that all the active sites of rubisco were full or that light intensity was now a limiting factor. Some needed to refer to the concentration of carbon dioxide rather than just carbon dioxide alone.

(ii) The majority of candidates stated the active site. Incorrect answers usually referred to some other part of the enzyme structure. The allosteric site was rarely stated.

(b) (i) Most candidates correctly stated carbon (dioxide) fixation or carboxylation.

(ii) A majority gave reduction or hydrogenation as their answer. Incorrect answers included phosphorylation, oxidation, dehydrogenation or redox.

(iii) Some candidates found this question challenging, although many answered it correctly with either five or six molecules. There was a range of other suggestions with eight being the most common incorrect answer.

(iv) This question was successfully completed by many candidates.

Question 9

(a) This was a well-answered question. Common errors included omitting to state that the receptors were located on the cell surface membrane or that the binding of glucagon would lead to the production of a G-protein, rather than cAMP or secondary messenger. Negative feedback was sometimes incorrectly given instead of homeostasis.

(b) (i) Many candidates gained full credit in this question. Most stated insulin secretion and glycogenesis. Some needed to be more precise by mentioning an 'increase' in uptake or referring to the cell 'surface' membrane. Glycogenesis was frequently stated.

(ii) Most candidates referred to glucagon in the correct context, but some contradicted themselves by stating that the glucagon directly caused glycogenolysis, rather than considering cell signalling.

Question 10

(a) This question was often well answered. The fact that zoos provide a safe environment, raise public awareness about endangered species and provide veterinary care were frequently stated. Research was often mentioned and a few scored credit by qualifying the type of research, such as behaviour or habitats.

(b) This 'suggest' question gave candidates an opportunity to express their ideas. Many mentioned the fact that the zoo was an unnatural environment and that this could lead to stress for the females or affect their reproductive cycles. Others referred to the lack of suitable males or that the females could just refuse to mate.

(c) Event **A** was explained in a variety of detailed ways, some of which were contradictory, whereas a mention of fertilisation was required for credit. For **B** and **C**, many stated that an embryo could be placed into another or surrogate female and some mentioned storing the embryo without reference to cryopreservation or freezing.

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A Level Structured Questions 43

Key messages

Candidates should be clear when referring to a specific membrane. If it is the membrane that surrounds the cell, it must be referred to as a cell surface membrane or a plasma membrane, as in **Question 6(d)**. If it is a membrane after the synaptic cleft is must be referred to as the postsynaptic membrane, as in **Question 9(a)(i)**.

General comments

There was a good range of marks awarded on this paper and it was found to be accessible to candidates of all abilities.

Most candidates found it more difficult to recall knowledge from the syllabus area of 19.2 Genetic technology applied to medicine, as in **Question 4(b)** and **Question 4(c)** and 16.3 Gene control, as in **Question 3**.

Comments on specific questions

Question 1

(a) Candidates were asked to identify substances in the Krebs cycle and the strongest candidates were able to do this accurately. A variety of answers were given when identifying the first Krebs cycle intermediate, citrate. The main errors made were with naming the coenzymes **Q**, **R**, **T** and **U**. Many candidates incorrectly wrote that the reduced coenzyme was oxidised for both types of coenzymes. Most candidates were able to identify carbon dioxide as a product of the Krebs cycle.

(b) This question asked for a description of how ATP was produced from ADP in the Krebs cycle. The majority of candidates were able to describe the transfer of a phosphate group to ADP. A large number of candidates used a correct equation to demonstrate this point. Fewer candidates were able to correctly name this reaction as substrate-linked phosphorylation. Some candidates who correctly named this reaction went on to contradict their answer by also adding that this happened during oxidative phosphorylation. A minority of candidates recognised that this reaction was catalysed by an enzyme. A few contradicted themselves by incorrectly naming this enzyme as ATP synthase.

(c) Many candidates found this question challenging. The majority recognised that one feature of ATP is that it is a small or water-soluble molecule; fewer were able to explain that this allowed ATP to move around the cell. Many candidates also incorrectly suggested that ATP would be moving around the body. The feature that most candidates could describe and explain well was that the loss of the phosphate group led to energy release and that this energy release was immediate or in small packets. Some were able to recall that $30.5\,kJ\,mol^{-1}$ is released. Some of the strongest candidates were able to achieve full credit; for others this topic proved to be an area for improvement.

Question 2

The strongest candidates were able to access full credit in this question. Most candidates knew that a mutation had occurred. There was also good knowledge of how the bacteria with the mutation would have a selective advantage so would survive and then reproduce. A few outlined the different types of gene transfer: vertical transmission and horizontal transmission. A good number of candidates recognised that the use of the antibiotic acted as the selection pressure with some also able to link this to the overuse of antibiotics or people not completing the full course of treatment. A minority were able to name this as directional selection. Many candidates used the neutral term 'changed' and needed to state 'increased' to show the effect on the resistance allele frequency to gain credit. It was rare to see the point that this type of evolution was fast due to the short generation time. It was evident that this area of the syllabus was not securely recalled by many. Weaker candidates often referred to the resistance gene having a selective advantage rather than the bacteria with that gene having the selective advantage.

Question 3

(a) (i) The majority found this very challenging and very few candidates were able to outline the main features of the *lac* operon as the promotor, operator and three structural genes. Some were able to correctly name *lacZ*, *lacY* and *lacA*. Those candidates who used **Fig. 3.1** achieved greater credit. Some missed out on credit because they did not write that there were three structural genes or if they named the structural genes, they did not name all of them, or there were errors in the names given. Many candidates misinterpreted the question and described the regulation of the operon. Many also wrote about *lacI*, but did not recognise that this was not part of the operon. There was also the misconception that transcription factors were a feature.

(ii) Candidates were asked to explain the role of the *lacI* gene here. The strongest candidates accessed full credit. They were secure in their knowledge that the *lacI* gene codes for the repressor protein, which binds to the operator and therefore blocks the promoter. They linked this to preventing RNA polymerase from binding to the promoter and preventing gene expression. Some also went on to explain that lactose when present binds to the repressor meaning that the repressor no longer stayed bound to the operator to allow gene expression to occur. The main misconceptions were: that DNA polymerase binds to the promoter, that the repressor binds to the promoter, that RNA polymerase binds to the operator, that lactose binds to the promoter, that the enzyme was called mRNA polymerase and that the *lacI* gene makes the repressor protein rather than codes for it.

(b) Candidates found this question very challenging and few were able to achieve full credit. Most candidates wrote about the *lac* operon, which is an inducible operon. Some recognised that the *trp* operon is repressible but did not explain how it was an advantage.

Question 4

(a) Most candidates were able to achieve full credit for this question.

(b) This question proved very difficult for the vast majority. Very few candidates achieved full credit, It was evident that most candidates were unfamiliar with this area and some candidates were unable to form any response. The main misconception was that the vector with the normal allele would insert the gene into a bacterium.

(c) There was a mixed response to this question about social and ethical implications. Some candidates from across the ability range were able to gain most of the credit available. The strongest candidates were able to achieve full credit. Many candidates needed to answer this question specifically referring to SCID rather than just discussing the use of gene therapy. There were many answers with vague references to it being wrong to 'play God' or that it was unnatural. Others suggested that a baby or child should give consent. Many thought that the gene therapy treatment would be used to create people with favourable characteristics or aesthetic modifications. There were many answers mistakenly suggesting that this type of gene therapy was a temporary treatment and not a cure. Some also thought that this would be germ-line gene therapy and that the new gene would be inherited.

Question 5

(a) The majority of candidates achieved full credit for this chi-squared calculation. Where mistakes occurred, it was usually due to a rounding error.

(b) Most candidates were able to compare the chi-squared value with the critical value and state which was higher. However, a large number then rejected the null hypothesis instead of accepting it. Most candidates were able to explain that the observed numbers were not significantly different to the expected numbers. However, there were candidates who wrote that the results were not significant and did not focus on the difference that would be not significant. Many candidates also added a correct statement about chance.

(c) The vast majority of candidates of all ability levels were able to correctly complete the Punnett square.

(d) Candidates found it difficult to achieve full credit with an explanation that was detailed enough. Many recognised that the **R** allele was located on the **Y** chromosome and needed to go on to explain that this would mean that all males would inherit the **R** allele.

(e) Most candidates gained some credit for this question. Most suggested that a mutation had occurred. A few of the most able candidates were able to identify that crossing over may have occurred where the **R** allele on the **Y** chromosome would have transferred to an **X** chromosome.

Question 6

(a) Candidates generally found this difficult. The most common error was to name the endothelial cell as an epithelial cell. Some confused the basement membrane with a basal membrane. Most candidates correctly named the podocyte.

(b) Most of the stronger candidates achieved full credit. Most identified the role of the basement membrane as a filter and that it prevented large proteins or red blood cells from passing through. Far fewer candidates knew that the filter prevented molecules more than 68 000–70 000 molecular mass from passing through.

(c) Most candidates were able to correctly work out the percentage and show their working. A small number did not show all their working or record their answer to more than one decimal place as instructed.

(d) The strongest candidates were able to achieve full credit in this question whereas some strong candidates found this question difficult. An error seen in many responses was to refer to the cell membrane and not the cell surface membrane or plasma membrane. Another was to state that the collecting duct became more permeable instead of the cells or membrane of the collecting duct. Some candidates were confused about the direction that water moved, mistakenly thinking that water moved into the collecting duct lumen. Some suggested that aquaporins worked by active transport, whilst others stated that water moved down a concentration gradient instead of a water potential gradient. It is always good practice to be clear about how a substance moves, e.g. if water, by osmosis, and to state where it moves from and where it moves to.

Question 7

(a) This question asked candidates to outline the sequence of events occurring in a sarcomere leading to its shortening after stimulation of the sarcoplasmic reticulum. Those candidates who recalled the names of the proteins and ions involved gave structured and detailed answers. Some stronger candidates were able to achieve full credit. Weaker candidates found it difficult to express themselves and missed out many important structures in their answers. One error seen in a small number of responses was that the binding site on the actin was an active site. Another large misconception was that ATP binds to the myosin head to be hydrolysed to cause the myosin head to flex and pull the actin along, not that the ATP binds to the myosin head to break the cross bridge. Candidates must take care to write out the symbol for calcium ions correctly with a 2+ charge and not 1+.

(b) Candidates were required to comment on the differences between muscle fibres of young and adult mice shown in a graph. Strong candidates were able to state that the young mice had a larger number of small diameter fibres but that the range of fibre diameters was greater in the adult mice. They then supported this statement by quoting data from the graph. A majority of candidates found it difficult to suggest how these differences would affect the sliding filament model of sarcomere contraction such as adult fibres having more actin and myosin resulting in a stronger contraction.

Question 8

(a) Candidates were presented with a diagram of a chloroplast and were asked to match statements about photosynthesis with locations in the chloroplast. Responses varied with only a minority able to match the location of a high concentration of protons with the thylakoid space.

(b) This question was well answered by many candidates. They were asked to describe the role of pigments in chloroplasts, apart from chlorophyll *a*. Many named another pigment correctly and referred to it as an accessory pigment that absorbed light and passed the energy on to the primary pigment. Others also mentioned that these pigments absorbed light not absorbed by chlorophyll *a*. Many weaker candidates were able to achieve full credit in this question.

(c) Many candidates were able to state that the absorption spectrum for whole chloroplasts was higher throughout and then attempted to support this with a data quote. The use of data was less well handled, and many figures were either inaccurate or did not compare the two spectra at the same wavelength of light. Explanations were more difficult with a minority of candidates able to suggest that whole chloroplasts had more pigments or that the pigments were arranged better for absorption.

Question 9

(a) (i) This question about a synapse was set in the context of dopamine in a brain synapse rather than a cholinergic synapse. Those who knew how a cholinergic synapse functioned and were able to apply their knowledge gave full and accurate answers. A common error was to mention depolarisation but not that it was the postsynaptic membrane that was depolarised.

(ii) Some candidates were able to link this question to the part of the syllabus concerning the *Tyr* gene and correctly named dopaquinone or melanin.

(b) Candidates were presented with a novel scenario whereby a different neurotransmitter, GABA, would cause an influx of chloride ions into the postsynaptic neurone. They were asked whether an action potential would be generated and to give reasons. A minority of candidates were able to show that the inside of the neurone would become more negative, making it difficult for depolarisation to occur, or for the threshold to be overcome and generate an action potential.

Question 10

(a) Many responses listed the differences between the kingdoms Animalia and Plantae. Where credit was lost, this was generally where candidates needed to give paired answers.

(b) (i) Most candidates were able to successfully calculate the rate of increase in temperature between 1980 and 2020.

(ii) Most candidates were able to gain credit by listing reasons why the moose populations had decreased in size. Climate change, less food and deforestation were among the most popular answers. Candidates of nearly all abilities were able to achieve full credit.

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Key messages

Candidates should read all parts of the question carefully and be prepared to critically evaluate unfamiliar scientific data in tabular and graphical forms. To access the highest grades, sound knowledge needs to be accompanied by application in suggesting conclusions and the ability to critically evaluate unfamiliar investigations.

When planning an investigation, it is important to set out the work in a logical way and for it to be detailed enough for another person to follow.

When planning such investigations, candidates should read the instructions carefully, especially when asked to not repeat details from previous questions, as no credit will be awarded for this.

General comments

Candidates were able to attempt all questions and the full range of credit was awarded. Very few candidates left answers blank.

Comments on specific questions

Question 1

(a) Most candidates were able to identify a variable that should be standardised. A significant number of candidates referred to carrot tissue even though the question stated this was not needed. Temperature was a very common incorrect answer.

(b) The majority of candidates correctly identified that the time taken would decrease as catalase activity increased. Terms such as more, less, higher and greater were accepted but candidates should use increase and decrease when describing a relationship. Errors often occurred when candidates referred to faster rising of discs and concentrations of catalase. These responses were not creditworthy.

(c) (i) This question was well understood by the majority of candidates. The most common incorrect answer was the length of the carrot.

(ii) Many responses were clear, logical and detailed, demonstrating a sound understanding of practical procedures, equipment use, the control of variables and the precautions required to minimise any risks. The highest scoring accounts made good use of the information provided and produced plans that could be followed with ease. Weaker responses did not indicate that a singular carrot needed to be used, often referring to collecting carrots of different lengths or cutting up many carrots. It was not necessary to give details of how to use the centrifuge to prepare the liquid carrot extract.

Candidates first needed to address the independent variable of cutting at least five different distances along a single carrot. Very few responses commented on the equipment they would use to cut and therefore the credit available for this idea was rarely awarded. Many candidates used at least the minimum of five distances along the carrot. Fewer identified that the mass/volume of the cut carrot should have been standardised for the experiment.

The rest of the investigation involved dipping the filter paper discs and measuring the dependent variable. Few candidates suggested stirring or mixing of the extracts before dipping the discs and so few gained credit for this point. Candidates demonstrated a clear understanding that the volume/depth of hydrogen peroxide should be kept the same and that the time for the disc to rise to the surface should be recorded. Responses also often suggested a method to maintain temperature and gave a suitable temperature range for enzyme experiments where stated.

Correct scientific terminology was important, and necessary, in a plan designed to be followed by another person. Candidates were clearly aware of the need to undertake repeats and calculate means, although many responses needed to make it clear that means should be calculated for each distance; many lost credit due to the lack of 'means' (plural) being calculated. When the experiment is to be repeated to enable a mean to be calculated, the number of repetitions is important; there should be at least three repeats. The term 'average' is not accepted as an alternative to mean.

To gain credit for precautions, candidates needed to identify the hazard, the specific risk, e.g. irritant, allergy, cuts to the skin, and the precaution required to avoid the specified risk. Many candidates identified hydrogen peroxide as an irritant and stated that gloves should be worn to avoid irritation of the skin. However, very few candidates could identify the mitigation for using a sharp implement. Many responses acknowledged the need for a control; boiled carrot and dead carrot were the most often incorrect controls given.

(d) (i) Candidates often referred to gas being produced rather than collected and therefore did not gain credit for the dependent variable. It is important to consider carefully exactly which variable is being measured in an investigation.

(ii) The vast majority of candidates correctly identified water in the heading of **Table 1.1**. Other incorrect answers included hydrogen peroxide and volume of gas. The calculated volumes were less well answered and it was evident that candidates required more practice at this skill.

(iii) This question proved challenging to candidates. **Fig. 1.7** and the suggested conclusions needed to be read very carefully. The command word 'evaluate' was used by some candidates to good effect; these responses stated reasons to support and not support the conclusion. Some candidates restricted their answers to only support or not support the conclusion; this meant their answers were unable to achieve full credit.

In support of the first conclusion, the vast majority of candidates correctly identified paired data quotes. In very rare occasions the candidates misread **Fig. 1.7** and did not obtain credit. Many candidates recognised that V_{max} required a plateau/levelling off of the graph in **Fig. 1.7**, therefore not supporting the second conclusion. Some candidates extended this further, noting that the range of concentrations used was limited. The fact that the investigation had not been repeated or that the gas collected might not only be oxygen was noted by fewer candidates. It is important that candidates give both sides in 'evaluate' questions, in this case, support and not support, as some only agreed with the statements given and did not offer an opposing point.

Question 2

(a) The question asked candidates to outline a laboratory method to determine the number of salmon lice needed to cause the death of a sea trout, so references to mark-release-recapture were not appropriate. Some candidates gained credit by suggesting that the scientists should add salmon lice to trout in a container of water and then count the number of salmon lice on any trout that died. A control experiment using trout with no salmon lice was often correctly suggested. Attaching glass beads or dead salmon lice to trout would not be practical. Candidates gained additional credit by suggesting key variables to be standardised such as the temperature/salinity of the water, or the age/mass of the trout.

(b) (i) Candidates were asked to state one variable that should be standardised in the electrofishing procedure. The location of the sampling site, the electric current and the time of year were often correctly suggested. References to standardising the time of day did not gain credit, as this may not be practical due to tides or weather conditions.

(ii) Many candidates noted that the small trout would continue to move in the water. To gain credit, candidates needed to state that the small fish would not be caught in the net and would therefore not be counted or recorded. A few candidates incorrectly assumed that the large fish being caught in the net would not be trout.

(c) (i) Several candidates correctly identified that the number of sea trout sampled each year were different. Candidates often stated that calculating the percentage of sea trout with attached salmon lice made comparisons easier or more accurate; this was not creditworthy. Those candidates who suggested that the comparisons would be valid, or fair were able to gain credit.

(ii) Candidates often noted that the mean percentage of sea trout with ⩾13 attached salmon lice was greater in year 2 than in year 1. Credit was only given if a suitable data quote (2.6% in year 1 increasing to 14.9% in year 2) or manipulated data from the same column of **Table 2.2** was used to illustrate this point.

(iii) Many candidates were able to suggest some limitations of the data shown in **Table 2.1** and **Table 2.2**. Candidates often stated correctly that no statistical test had been carried out. Several candidates also noted that the sampled sea trout had no attached salmon lice in year 1 and year 2 of the production cycle in 2004–2005. Stating that the sample size was too small was not sufficient to gain credit; this statement needed to be expanded to explain that the number of sea trout sampled was too small or that more production cycles should be studied. Noticing that no data was collected for ⩾13 salmon lice in 2000 and 2001, or that the study was only carried out at one location (Shieldaig) did not gain credit.

(d) (i) Many candidates showed a good understanding of the null hypothesis, stating that there was no correlation between the number of salmon lice on sea trout and the distance from the nearest fish farm. A common error was to state that there was 'no difference' rather than 'no correlation/relationship'. A few candidates stated an alternative hypothesis rather than the null hypothesis.

(ii) This was answered correctly by just over half of the candidates. Candidates should be aware that when $p \leqslant 0.05$, the statistical test is significant.

(iii) There were many good answers here gaining credit for stating that as distance from the nearest fish farm increases, the number of salmon lice decreases.

(iv) Many candidates found this question challenging. Those who had learnt a valid definition for 95% confidence limits gained credit by stating that there is a 95% probability that the true mean lies within the limits. The idea that 95% confidence limits show how close the calculated mean is likely to be to the true mean was also creditworthy. Care should be taken to clearly state which mean (true or calculated) they are referring to. Several candidates noted that the error bars overlapped; this alone did not gain credit, but responses that suggested that the 95% confidence limits were calculated to see if the error bars overlapped were creditworthy. Full credit was only given to those candidates who referred to **Fig. 2.3** in their answers. Good responses stated that the 95% CI error bars for Scotland overlapped, so the difference between the means may not be significant. Additionally, some 95% CI error bars for Ireland did not overlap (e.g. 5 km and 15 km) so the difference between the means is significant.

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Key messages

Candidates should always read and process the essential information provided on the examination paper before attempting to answer the questions. Clarity of expression and the use of correct scientific terminology is required.

Where questions specify that one or two pieces of information are required, candidates should follow this instruction. Writing lists of all possible answers can be detrimental. An incorrect answer at the start of a list can limit the number of marks awardable.

Any sketch graph should be drawn with as much precision as possible using a sharp pencil.

Attention should be paid to the command words used in the question stem to ensure the focus of the response is correct.

General comments

The full range of marks were awarded, with most candidates attempting all questions. Candidates should read every line of the question paper to avoid missing a question, for example, **Question 1(c)(ii)** required a line to be drawn on the graph above; this was missed by some candidates.

Some responses contained abbreviations; candidates should ensure that the meaning of these abbreviations is made clear.

Calculation questions were answered well and most candidates included some intermediate working.

Comments on specific questions

Question 1

(a) Many candidates gained credit for recognising that one part enzyme should be added to nine parts distilled water. Incorrect answers suggested mixing one part enzyme to ten parts distilled water, adding ten times the volume of water or simply stating a method of dilution.

(b) (i) pH was correctly identified as the independent variable in most responses. Candidates should be careful when answering using a full sentence as some responses gave the impression it was the effect of pH that was the independent variable rather than the pH values. With 'state' as the command word, only a single word or phrase is necessary.

(ii) Candidates were able to identify a standardised variable, with 'the temperature of the solutions' being the most frequent answer. Incorrect answers included 'concentration of substrate' and 'volumes of the solutions'. No information regarding the volumes was provided in the stem of the question.

(c) (i) The majority of responses made correct calculations using data from the graph. Calculations were written clearly and the source of the figures was indicated on the graph. Candidates were expected to use the figures between 0 and 30 s and 0 and 0.26 au as this section of the graph was a straight line. Correct calculations were made using data from a correctly drawn tangent starting at the origin and extending to the top of the grid provided. Weaker responses used the whole graph to calculate a rate or used figures from an incorrect tangent.

(ii) Although the question asked for a line to be sketched, candidates should be aware that precision and clarity are required. As this was a question related to the impact of pH on enzyme activity, the line drawn needed to make it clear whether the absorbance was continuously increasing, levelling off, or rising and then falling over time. There should be no ambiguity. Many sketched lines did not show this level of clarity. The use of a sharp pencil is recommended.

(d) The highest quality answers to this question included details about how and when named equipment was to be used and which variables were controlled and how that control was achieved. These responses were clear and concise, had numbered stages for the procedure and included details about volumes, times, temperatures and use of data, overall producing a method that was specific and workable. Weaker responses included details repeated from the question, unnecessary details, and lists of the variables without the information on how these were being controlled. Abbreviations, e.g. CV and IDV were seen; candidates should be aware that the full meaning of these must be made clear. The use of non-scientific terminology was also seen. ‘Average’ is not acceptable for ‘mean’ and ‘amount’ is not acceptable for ‘volume.’

Many clear responses included a table to show how a suitable range of five different concentrations could be produced. Other responses included detailed written descriptions on how the dilution was carried out. Some weaker responses in this format were confused, incomplete or muddled. Errors included dilutions greater than 0.2%, not using the concentration units given in the stem of the question and incorrect positioning of the decimal point, 0.5% written instead of 0.05%. The equation $M_1V_1 = M_2V_2$ was seen, however candidates also needed to include examples of how this equation would be used.

To gain full credit, responses needed to describe how equipment should be used to control variables, how dilutions are to be prepared and how to set up apparatus, such as the colorimeter. Many generic statements were seen in weaker responses, for example ‘use a water-bath’ and ‘calibrate the colorimeter.’ Stronger responses included the temperature of the water-bath and a description of its use, stating clearly that the tubes with the solutions were placed into the water-bath to equilibrate. With reference to the colorimeter, responses would be expected to include how and when it was calibrated.

Candidates were aware that a control should be included in the method. A small proportion of candidates understood that the control would be using a denatured enzyme or using water to replace the enzyme. Most responses gave 0% substrate as the control.

A regular part of any method involves repeats to obtain mean values. A basic statement ‘repeat three times and calculate the mean’ is an insufficient description. In this method a mean needed to be calculated for each of the different concentrations, so for the whole experiment several means would be calculated. High-scoring responses included clear statements which indicated that a mean was calculated for each of the different concentrations. Weaker responses suggested that only one mean value was calculated for the whole experiment. The aim of the method was to generate data to determine the effect of concentration on the rate of the enzyme-catalysed reaction and this was obtained by calculating the mean absorbance value for each of the concentrations in a set time. A few responses made reference to how the data collected could be used to calculate that rate.

(e) The clearest responses demonstrated an understanding of the scientific method and how the use of statistical analysis should be used to indicate the reliability of the data. Strong responses were concise and identified the details that meant the conclusion could not be supported. The question was often answered in a narrative style which only covered one aspect, usually that the plant source of polyphenol oxidase was different/not the same for all anti-browning agents. The mark allocation indicated to candidates that more than one aspect was required. Weaker responses were often muddled, confusing the anti-browning agent with the enzyme or attempting to analyse the data from the table.

(f) Candidates needed to use knowledge of the standard graphs that illustrate the impact of pH on enzyme activity. The sketched line needed to clearly demonstrate the levelling off/lower V_{max}. The use of a ruler is recommended.

Question 2

(a) (i) Candidates were required to read the information about lichens carefully in order to answer the question. Incorrect responses focused on information about the grid that was provided in the stem and so missed the specific emphasis of the question. Candidates were asked to state what should be standardised rather than what was standardised. It was noted that many responses were lists of variables. Candidates must be selective in their choices as incorrect suggestions may negate correct answers given.

(ii) Strong responses used the information provided to gain full credit. This was achieved by identifying a hazard, the risk that specific hazard posed and then linking that to a specific precaution. Weaker responses provided generic precautions such as ‘wear gloves/mask/goggles’ but this was not always appropriate to the risk identified. For risks linked to toxicity or poisoning the precaution should be linked to preventing ingestion or toxins entering the body through broken skin rather than just skin contact. The terms ‘harmful’ and ‘infectious’ were too general to gain credit.

(b) Many responses gained full credit for accurate counting and calculation of a percentage. Candidates are advised to check their counts carefully in such questions; some responses lost credit due to miscounting of the white and black dots.

(c) (i) A very large proportion of candidates gained credit here. Incorrect answers indicated a lack of understanding of this statistical test. These candidates needed to use the information provided in the table headings and the formula below the table to clarify what was required.

(ii) Many candidates gained full credit. Those who did not gain credit missed the instruction to state the value to three significant figures. Candidates are advised to check all calculations if no working is being included in their answer. It was evident from responses where working was shown that transposition errors were being made.

(iii) Some responses indicated a lack of understanding about the specific focus of the question, and some answers to **Question 2(c)(iv)** were written in response to this question. A large number of responses correctly stated that a positive correlation was present, fewer were able to further qualify the correlation as a strong one.

(iv) Understanding of the use of this statistical test was found to be challenging for candidates. To gain full credit, responses needed to be clear and unambiguous, written with thought and with the selective use of appropriate terminology. Many good responses were seen which described the implications of the calculated r_s value being higher or lower than the critical value. The incorrect use of terminology resulted in weaker responses that were unable to gain full credit. The term ‘critical’ was lacking in some answers, others indicated that the critical value was 0.05, and the symbols < and > were sometimes muddled. Other responses suggested a misconception that probability levels and confidence levels are fully interchangeable terms. Candidates should be aware of the difference and express their responses in clear terms using either probability or confidence levels but not both. Some responses referred to the results or data being due to chance, rather than the correlation.

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Key messages

Candidates should read each question carefully before starting to write their answers.

When planning an investigation, it is important to make sure of the investigation being asked and to set out the work in a logical way.

When calculation questions state 'show your working', full credit is only given to correct answers with correct working.

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

General comments

Question 1

This question considered an investigation using the aquatic protoctist *Chlorella vulgaris* immobilised in alginate beads. Candidates were asked to design an experimental method to determine the effect of light intensity on the rate of photosynthesis of *C. vulgaris* using hydrogencarbonate indicator. Candidates were then introduced to two methods that could be used to determine the number of cells per cm^3 in a suspension of *C. vulgaris*.

Question 2

This question considered an investigation into the effect of grazing by red deer on the abundance of salted shield lichen. Data from the investigation was then analysed by candidates; this included interpretation of the results from a *t*-test.

Comments on specific questions

Question 1

(a) Candidates were asked to explain the colour change seen when alginate beads with immobilised *C. vulgaris* were left in a container of hydrogencarbonate indicator and exposed to light. Many responses correctly stated that the colour change from red to magenta showed an increase in pH or a decrease in carbon dioxide concentration. It was important to state that the 'carbon dioxide concentration increases' and not just that 'carbon dioxide increases'. Most candidates knew that the colour change was due to the photosynthesis of *C. vulgaris*; those answers that clearly stated that photosynthesis uses carbon dioxide were given credit.

(b) (i) Most candidates correctly identified the independent variable as the light intensity. Only a few candidates confused the dependent and independent variables.

(ii) Candidates were often familiar with this style of question and most were able to describe some aspects of a suitable method to investigate the effect of light intensity on the rate of photosynthesis of *C. vulgaris* using hydrogencarbonate indicator. A few candidates gained full credit for this question.

Changing the distance from the apparatus to the lamp was the most common method used to vary the light intensity. Many candidates suggested at least five different distances to test so that a meaningful graph could be plotted showing the relationship between light intensity and rate of photosynthesis. Some candidates suggested other valid methods to vary light intensity, such as light bulbs of different voltage. Strong responses also measured the light intensity, for example by using a light meter.

Most candidates considered the variables that would need to be controlled in this investigation, such as background light, the number of alginate beads and the volume of hydrogencarbonate indicator. References to using a water-bath to standardise temperature did not gain credit as this would not be a feasible option for the experimental set-up. Instead, a heat shield or a cold light source should be used to minimise the heating effect of the lamp. A suitable control experiment using hydrogencarbonate indicator without any alginate beads was suggested by a few candidates.

The responses given by the majority of candidates clearly stated the measurements that should be taken; most noted the colour of the hydrogencarbonate indicator after a fixed period of time, such as 12 hours. Few candidates considered using a colour chart or pH meter to improve the accuracy of the measurements. Use of a colorimeter would not be appropriate for this investigation. Most candidates recognised the need for replicates in the investigation and linked these to the calculation of a mean. To gain credit, responses needed to state clearly that at least three replicates should be used to calculate a mean for each light intensity. The term ‘average’ should not be used in a scientific context.

The majority of 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.

(c) Candidates were asked to predict and explain the results if alginate beads with immobilised *C. vulgaris* were left in the dark for 12 hours. Common incorrect responses stated that no change would occur because photosynthesis does not take place in the dark. These candidates needed to consider the effect of the respiration of *C. vulgaris*. Respiration produces carbon dioxide and therefore will cause the hydrogencarbonate indicator to decrease pH and turn yellow.

(d) (i) Most candidates correctly read the graph in **Fig. 1.4**, giving 5.36 as the $\log_{10}$ of cells counted per cm^3 suspension. To avoid error, candidates should use a ruled guideline and take care when reading the scale. Several candidates were unable to calculate the correct answer. Those candidates who were familiar with logarithms mostly rounded their answer to 229 000 cells and therefore gained full credit.

(ii) The majority of candidates were able to correctly count 24 cells in the counting chamber. Candidates were then required to find the volume of the counting chamber in order to calculate 240 000 as the number of cells per cm^3 of suspension. The conversion between mm^3 and cm^3 caused difficulty for some candidates.

(iii) This question asked for two reasons why using a Secchi stick is less accurate than using a counting chamber. Several candidates correctly stated that the Secchi stick is subjective as different people may observe the circle disappearing at different depths. Additionally, the ruler has an error of ± 0.5 mm, the Secchi stick may not be held vertically, and no repeats of the measurement were carried out. Some of the strongest responses stated that inserting the Secchi stick might disturb the suspension or that the Secchi stick used by the scientists might be different from the one used to construct the calibration curve.

Question 2

(a) (i) Candidates were asked to state two variables that should be standardised when investigating the abundance of salted shield lichen on tree trunks. The species and size of the tree were often correctly identified. The age or aspect of the tree, and the height of the sampling grid above the ground could also be standardised. References to standardising the ‘time of sampling’ did not gain credit, as this has already been stated in the information given in the question.

(ii) Most candidates were able to identify a relevant hazard and state the risk that this might pose to the scientists. For example, a plant might cause irritation, or lichens might result in an allergic reaction. Several candidates stated risks that were due to the environment such as trip hazards or falling branches; credit was only given if these hazards were linked to the risk of injury to the scientists. Further credit was given to the majority of candidates who also stated a safety precaution that matched the risk they had identified. A few candidates misread the question and discussed the harm that might be caused to the lichens during the investigation; this did not gain credit.

(b) Many candidates were able to correctly calculate the number of circles on the sampling grid that contained salted shield lichen as 57, giving their answer to the nearest whole number as required by the question.

(c) (i) The majority of candidates were able to give the correct null hypothesis, stating there was no difference in the abundance of salted shield lichen between the exclosures and grazed areas. Common errors were to state that there was no correlation rather than no difference, or to refer to the amount of lichen rather than the abundance. A few gave the alternative hypothesis.

(ii) A number of conclusions can be made from the data in **Table 2.1**. Candidates were able to conclude that there is no significant difference between the exclosures and grazed areas for the base of the tree trunk. Alternatively, candidates were able to conclude that there is a significant difference between the exclosures and grazed areas for both the middle and upper parts of the tree trunk. The phrase 'no significant difference' should be used rather than stating that the difference is 'insignificant'. Several candidates gained credit by correctly describing the trend: the percentage cover of salted shield lichen is greater in grazed areas than in exclosures. A few candidates correctly noted that the percentage cover of salted shield lichen increases as the height of the grid increases. References to percentage cover or abundance that were not linked to the lichen did not gain credit.

(iii) The strongest responses considered whether the scientists could reasonably compare the results from the exclosures with the results from the grazed areas. To do this the scientists should check whether the abiotic and biotic variables are similar in the two areas. Named abiotic variables that gained credit included light intensity, temperature and rainfall. Some candidates suggested that biotic variables such as other plant species or other animal species should be similar in both the exclosures and grazed areas. It is not appropriate to exclude all other animals that might graze on the salted shield lichen. A very few candidates noted that the range of different tree species in the two mixed woodland areas (exclosures and grazed) should be similar. Variables that were standardised in the original investigation in **Question 2(a)(i)**, such as the time of year and age of tree, were not creditworthy. However, candidates could gain credit by stating that the investigation should be repeated in more years following the original investigation in 2013.