BIOLOGY

Paper 9700/11
Multiple Choice

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

General comments

Ten questions (**5**, **10**, **11**, **14**, **16**, **26**, **27**, **28**, **29** and **39**) were found to be relatively straightforward and ten questions were relatively difficult (**2**, **4**, **9**, **17**, **19**, **22**, **23**, **24**, **33** and **35**). The topic of transport in plants was well understood; there was lower confidence in the understanding and application of knowledge on the topic of nucleic acids and protein synthesis.

Comments on specific questions

Question 2

This question assessed an application of knowledge about the function of the nucleolus. Many candidates wrongly thought that transcription (option **C**) occurred in the nucleoli, rather than the assembly of ribosomes (option **D**). Careful reading of the question was required because the terms 'nucleoli' and 'nuclei' are similar to each other.

Question 4

A similar number of candidates chose options **B**, **C,** and **D** for this question on the location of nucleic acids in the listed cell structures. This suggests that most candidates knew that ribosomes contained the nucleic acid RNA. The two wrong options **B** and **D** included Golgi bodies, suggesting that these candidates had confused post-translation modification with the earlier steps in protein synthesis where nucleic acids would have been involved.

Question 9

This question required candidates to use information and a diagram of part of a cellulose molecule to explain how the hydrogen bonds help in its function as a suitable material for cell walls. Except that only very few candidates selected option **C**, there was no clear pattern in which option was chosen by the candidates.

Question 17

Most candidates correctly calculated the surface area to volume ratio of the cuboid as 23:12. Similar numbers of candidates selected that the surface area to volume ratio would increase (option **D**) if the cell width doubled, as correctly suggested that the ratio would decrease (option **C**).

Question 19

Almost all candidates excluded option **C** from their choice of explanation for the observations from an investigation into four different treatments on permeability of cell membranes in beetroot cells. Those candidates who chose option **A** had correctly linked low pH with the denaturation of proteins, but the observation was incorrect. Those candidates who chose option **D** had selected a correct observation, but an incorrect explanation.

Question 22

Nearly half the cohort correctly selected option **D** as the stages in the mitotic cell cycle when DNA ligase and RNA polymerase are used. The most common incorrect choice was option **A**, suggesting that these candidates realised that neither enzyme is used during mitosis, or that the nucleus is only present during interphase.

Question 23

Most candidates excluded statement 1, that an incorrect nucleotide is added to a DNA molecule during transcription, from the choice for this question on how a gene mutation can lead to the production of a non-functional protein. Many of these candidates did not realise that statement 3 was also incorrect and opted for **D** rather than **C**.

Question 24

Almost half the cohort correctly realised that there would be the same number of DNA molecules in early prophase and telophase, and that this would be double the diploid number (option **C**). A significant minority suggested that the number of DNA molecules will have returned to the diploid number by telophase and selected option **D**.

Question 33

Many candidates correctly selected option **D** to describe how most tissue fluid is returned to the blood at the venule end of a capillary. Similar numbers of candidates selected options **A** and **B**, highlighting common misconceptions about the permeability and hydrostatic pressure of capillaries respectively.

Question 35

The vast majority of candidates correctly identified the tissues present in the trachea. Approximately half the cohort incorrectly thought that smooth muscle is also present in alveoli and selected option **B** instead of option **A**.

BIOLOGY

Paper 9700/12
Multiple Choice

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

General comments

There were eleven questions (**2**, **5**, **13**, **23**, **24**, **25**, **26**, **29**, **31**, **33** and **39**) that were found to be fairly straightforward and another nine questions that were relatively difficult (**1**, **6**, **7**, **14**, **17**, **20**, **30**, **32** and **36**). A few of the least demanding questions relied on knowledge of the structure of nucleic acids. Other well-answered questions involved labelling diagrams and selecting the correct row in a table of information. Some of the most challenging questions required manipulating data and very careful reading of the options, particularly on the structure and properties of biological molecules such as collagen, haemoglobin, and phospholipids.

Comments on specific questions

Question 1

This question required candidates to realise that the actual measurements of structures and their positions relative to each other are not affected by magnification. Nearly half the cohort understood this and selected option **C**. A considerable number of candidates opted for one of the other three answers that involved a calculation with the change in magnification.

Question 6

Only a few candidates read this question carefully and correctly identified bond X as a covalent bond that makes a cross-link between collagen triple helices to form a fibril. Many candidates selected hydrogen bonds (option **C**) as the bonds that are required to hold the triple helices together.

Question 7

Some candidates correctly used the data in the table to calculate that more than 1% of the residues in haemoglobin are cysteine (option **A**); others incorrectly suggested that a reduced Bohr shift would result in a decreased affinity of haemoglobin for oxygen at a low pH.

Question 14

This question required candidates to consider the structure and bonding that occurs to form a phospholipid. Although most candidates correctly calculated the number of each of the component molecules that are used to synthesise phospholipids, most candidates did not realise that the formation of a phospholipid would also require three condensation reactions. These candidates did not subtract the molecular weight of the eighteen water molecules that would be removed to form six phospholipids from their total. This meant that they came to an answer of 4506 $g mol^{-1}$ (option **C**), rather than the correct answer of 4182 $g mol^{-1}$ (option **B**).

Question 17

Some candidates correctly calculated the surface area to volume ratio of the cylindrical bacterium to give the correct answer, option **B**. Many others used the diameter rather than the radius in the calculations, leading them to one of the incorrect answers.

Question 20

Almost all candidates knew that bonds form between nucleotides in a DNA strand (statement 2) during the mitotic cell cycle. However many candidates thought this was the only correct statement (option **D**). These candidates had not considered that all living cells, including bone marrow cells, are always in one of the stages of the mitotic cell cycle and therefore the processes described in statements 1 and 3 will also occur (option **A**).

Question 30

Slightly more than half of the candidates incorrectly thought that point **B** on the graph indicated the start of atrial systole. This unfamiliar plot, showing the volume changes in the left ventricle, started at ventricular systole and so atrial systole is at point **C**.

Question 32

Almost all candidates knew that the outer layer of an artery contained collagen and elastic fibres, reducing their options to **B** and **C**. However, many candidates did not choose the correct option **C**, where the inner endodermal layer was described as a smooth layer of squamous cells.

Question 34

This question, comparing the gas exchange system of an insect with the gas exchange system of a human, challenged those candidates who had not read the annotations carefully enough. The most common wrong option was **B**, suggesting that those candidates had not noticed the label on the right-hand side identifying the multiple tracheae in the electron micrograph of the insect gas exchange system.

BIOLOGY

Paper 9700/13
Multiple Choice

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

General comments

Ten questions (**2**, **3**, **6**, **16**, **19**, **21**, **29**, **32**, **35** and **36**) were found to be straightforward in this paper. In contrast, candidates found a different ten questions relatively difficult (**8**, **14**, **20**, **22**, **24**, **25**, **27**, **28**, **31** and **33**). There were no clear patterns with respect to which topics or question styles that proved to be particularly challenging. There were only slightly more correct responses to questions that focused on assessment objective 1 compared with those on assessment objective 2.

Comments on specific questions

Question 8

Many candidates answered this correctly, selecting option **A**, but some incorrectly selected option **B**. The enzyme was formed from two polypeptides, which meant that a quaternary level of protein structure would also be involved in controlling the shape of the active site.

Question 14

Slightly over half of the cohort answered this correctly, selecting option **C**, a number of other candidates selected option **D**. These candidates considered the function of mitochondria rather than the context of preparing them for microscopy.

Question 20

This question identified the common misconception that chromosomes only form into sister chromatids with a centromere during mitosis (option **D**). Approaching half of the cohort knew that, although condensation of chromatids and attachment to the spindle fibres occurs in the early stages of mitosis, the joining of sister chromatids to their centromeres starts in G2 of interphase (option **A**).

Question 22

The most common wrong answer to this question on XNA was option **B**. These candidates knew that the bases were responsible for coding and excluded options **C** and **D**, but some candidates did not realise that the first part of a nucleic acid (X) is a five-carbon sugar (option **A**).

Question 24

Only half of the cohort knew that condensation, polymerisation, and transcription occur during the formation of mRNA (option **B**). Options **C** and **D** were both common wrong answers. Both these options included replication, a process required for synthesising new DNA molecules, not RNA.

Question 25

Many candidates correctly selected option **D**. A considerable number selected option **C**, implying that they had identified the DNA triplet 'CTT', but not worked through that the anticodon would have the same bases as the triplet in the DNA template strand.

Question 27

Option **C** proved to be a strong distractor for this question on the structure of sieve tube elements. These candidates did not show awareness that these cells do not contain nuclei.

Question 28

Although many candidates identified the correct statement (option **B**) about translocation in phloem, some incorrectly suggested that glucose is moved into the sieve tube via companion cells (option **D**). The cotransport of assimilates from companion cells involves sucrose and amino acids and not glucose.

Question 31

A similar number of candidates selected options **B** and **C** on this question on the events at the start of ventricular diastole. This is a particularly difficult series of events to visualise without a diagram. Option **C** would have been correct if the question has asked about ventricular systole, rather than the diastole.

Question 33

Some candidates incorrectly selected option **A** for this question on the formation of tissue fluid. Although the hydrostatic pressure is higher in the capillaries at the arteriole end of the capillary, it does not increase. The correct annotation is option **C** which describes how water moves back into the capillary at the venule end.

BIOLOGY

Paper 9700/21
AS Level Structured Questions 21

Key messages

Questions may contain information that is a mix of the familiar and the unfamiliar. It is essential that candidates read and assimilate the text and any accompanying diagrams, photographs or data before reading the questions that follow. Candidates should avoid the temptation to rush straight to answering the question because they are likely to miss out on helpful stimulus material that could be used to develop a response and allow them to achieve to the best of their ability.

Questions such as **Question 4(b)(ii)**, **Question 5(a)(i)** and **Question 5(a)(ii)** presented candidates with an unfamiliar investigation that was accompanied by data, which needed to be analysed. These questions were well attempted by some candidates, who showed good mathematical skills and who applied knowledge and understanding from different parts of the course, including practical work.

Question 2(c)(ii), **Question 3(b)(ii)**, **Question 3d(ii)**, **Question 4(c)** and **Question 6(c)** are further examples where candidates were required to apply their knowledge and understanding to unfamiliar contexts and to use knowledge from across the syllabus. Candidates who read widely and who are most familiar with the syllabus learning outcomes that are covered during the course are more likely to be confident when answering questions and approaching this style of question in an examination situation.

General comments

There was a great deal of evidence that candidates had prepared thoroughly for the examination as many were able to show a strong understanding of the syllabus content and performed well on this examination.

Familiarity with the Bohr shift helped candidates to answer **Question 2(c)(i)** and **Question 2(c)(ii)**, with many successfully applying this knowledge to the unfamiliar example of the penguin swimming underwater.

Question 4(b)(i) was challenging for many candidates who were unable to identify the sieve plate accurately. It is important that candidates learn appropriate scientific names for structures in both animal and plant biology. Spelling of key terms is also important as incorrect spelling was the main reason candidates were unable to gain credit for **Question 3(b)(i)**. Knowledge of appropriate language was important in order to gain full credit for **Question 6(c)** and the strongest answers made the link between microtubules mentioned in the question and spindle fibres in the photomicrograph shown in **Fig. 6.1**.

Candidates should check that they have produced a response to all question items (part-questions) in the examination paper. Each question item is associated with a mark appearing in square brackets. In this paper, there were no answer lines for **Question 2(c)(i)**, which needed a line drawing on a graph, and **Question 6(a)**, which needed a label adding to an image. These two items were sometimes not answered by candidates who were otherwise tackling all other part-questions in the paper, suggesting that they had not checked that each question had been fully answered.

Comments on specific questions

Question 1

(a) This question assessed knowledge of cell structure in three main types of cell: animal, plant and prokaryotic. The majority of candidates were able to gain partial or full credit for completing **Table 1.1**. Most candidates knew that the large permanent vacuole is found only in the plant cell. The strongest candidates were able to correctly identify that centrioles are found only in animal cells. Many thought that they would also be in prokaryotic cells. The column for the animal cell was most frequently completed correctly.

(b) (i) The microvilli in **Fig.1.1** were identified by many candidates. The most common incorrect answer was cilia. Some candidates gave two answers, villi and microvilli and were not able to gain credit because villi is an incorrect answer.

(ii) The majority of candidates were able to identify the mitochondrion in **Fig.1.1** and state a correct function for this organelle. As energy cannot be produced during respiration, this description of the function of a mitochondrion was not given credit. Only the strongest responses considered the information provided about the role of the cell to explain that the mitochondrion provided ATP or energy for the absorption of digested food by active transport or endocytosis. Strong answers also used the term for a single mitochondrion and avoided using the plural term, mitochondria.

Question 2

(a) The majority of candidates were able to complete **Fig. 2.1** by writing 'arterioles' and 'venules' in the correct order to show the five types of blood vessel in the circulatory system. The most common incorrect answers confused the names of the blood vessels with the names of chambers of the heart. A small number of candidates left this question blank. Candidates must read every part of the question paper carefully to make sure that they do not miss questions which are not answered on answer lines and require, as this question did, labels to be added to a diagram.

(b) Most candidates were able to identify water as a polar molecule, and a proportion of these were able to correctly explain what this meant, by describing the delta positive hydrogen atoms and the delta negative oxygen atom. Some candidates described water as charged with positively charged hydrogens and a negatively charged oxygen, which was not accurate enough to be credited. Care should be taken when using scientific terms to describe water as a solvent. It is important that the terms atom, molecule and ion are used correctly. The strongest responses made use of the information in **Fig. 2.2** to explain how the polarity of water molecules allows water to act as a solvent, separating the ions. Candidates who found it challenging to explain the process of dissolving in detail were able to gain some credit for showing an understanding of water molecules being attracted to the sodium chloride.

(c) (i) A good proportion of candidates were able to use the information provided in the question stem and knowledge of the oxygen dissociation curve to draw a line on **Fig. 2.4** to the left of the printed line. The majority of candidates started the line at zero.

(ii) This was a challenging question for the majority of candidates. Most who gained credit recognised that the decrease in pH would allow oxygen to be released from haemoglobin. Some candidates recognised this as the Bohr shift and gained credit for this knowledge**.** The strongest responses were able to link the decrease in pH to an increase in hydrogen ion concentration and a reduction in the affinity of haemoglobin for oxygen. Only the strongest candidates finished their explanation by linking the release in oxygen to aerobic respiration in muscle cells, which allows the penguin to continue to swim underwater.

(d) Many candidates were able to state the full name of the group of specialised cells in the wall of the right atrium. Weaker responses gave the acronym SAN and were not able to gain credit for this because the question asked candidates for the name of the group of specialised cells. Some candidates confused the sinoatrial node with the atrioventricular node.

Question 3

(a) This question, which was well answered by many candidates, assessed the ability to identify two types of tissue present in a photomicrograph of part of the wall of a bronchus and the ability to make a comparison related to these tissues between the wall of a bronchiole and the wall of the bronchus. Tissues **J** and **K** present in **Fig. 3.1** were usually accurately identified, with tissue **J**, cartilage, proving to be more familiar to candidates than tissue **K**, smooth muscle. The two most common spelling mistakes for cartilage were 'cartilidge' or 'cartlidge'. Candidates who simply wrote 'muscle' for tissue **K** did not gain credit as this was not the precise identification. Weak responses confused the tissues in **Fig. 3.1** with other tissues or cells found in the walls of the gas exchange system including elastic tissue, squamous epithelium, goblet cells and ciliated cells. The majority of candidates who identified cartilage correctly were then able to state that cartilage is found in the bronchus but not the bronchiole. Descriptions of the difference for smooth muscle in the two walls was less precise, with only a few correctly suggesting proportionately more smooth muscle is present in the wall of the bronchiole than the bronchus.

(b) (i) A good proportion of candidates were able to state, and spell correctly, the binomial name of the species of pathogen that causes tuberculosis (TB). *Mycobacterium tuberculosis* and *Mycobacterium bovis* were equally acceptable. The most common error was to spell the generic name incorrectly. Incorrect spellings included '*Microbacterium*' and '*Mycrobacterium*'. The generic name should be written with a capital (uppercase) letter and the specific epithet with a lowercase letter. Very weak responses named species (frequently spelled incorrectly), such as *Vibrio cholerae* and *Plasmodium falciparum*, which cause other diseases.

(ii) Most candidates who gained credit identified the antigen binding site or variable region for the part of the monoclonal antibody that binds to the protein from the pathogen. Some candidates incorrectly stated this to be the active site and did not gain credit. A small number of candidates gave the answer as 'binding site'. This was not credited as it was not sufficiently precise.

(iii) Candidates were not expected to have learnt about the test strip for TB, and had to apply their knowledge and understanding of monoclonal antibodies, antibody structure and antigens to suggest why the test is specific for TB. The strongest responses described the complementary shape of the antigen binding site and the antigen, and also explained that the antigens on the surface of the pathogen causing TB are specific and not found on any other pathogen. Reference to the complementary shapes of the antigen binding site and the antigen on the surface of the TB pathogen was important. Weaker responses that included the idea of complementary should also have mentioned shape to gain credit. The monoclonal antibodies with the gold particles attached were also shown in **Fig. 3.3**, and a small number of candidates included a correct reference to these in their answer.

(iv) Generally, candidates showed a good understanding of the specificity of antibodies and made good suggestions about how the structure of the immobilised monoclonal antibodies in area **3** of the test strip for TB differed to those in area **4**. It was important to emphasise that the antigen binding sites have a different shape, rather than just stating that the antigen binding sites were different. This shows an understanding that the immobilised monoclonal antibodies in area **3** have antigen binding sites with a complementary shape to the protein secreted by the pathogen, and the immobilised monoclonal antibodies in area **4** have antigen binding sites with a complementary shape to an area of the monoclonal antibody attached to the gold particle. The strongest responses used biological terminology effectively to describe differences in protein structure, such as variable region, tertiary structure and named bonds in the tertiary structure. Weaker responses were too imprecise to be creditworthy, for example stating that the antibodies had different amino acids.

(c) The role of memory T-lymphocytes in providing protection from TB was identified by the strongest candidates, who were able to describe this as providing immunity and then show the link between memory T-lymphocytes and features of a secondary immune response. Credit was not given for stating 'immunity response'. For this question, it was acceptable to describe the secondary immune response as a fast or strong response, but reference to 'immune response', without further qualification, was not credited. Fewer were able to develop their ideas to describe the role of memory T-lymphocytes in more detail, such as the activation by the foreign antigen on the invading pathogen. Some candidates confused the terms pathogen and antigen when trying to describe this activation. Some responses included detail of the role of T-helper cells, but weaker answers confused their role with that of T-killer cells, suggesting cytokines could be used to kill infected

cells. A common error was to describe the role of B-lymphocytes rather than T-lymphocytes, which highlighted the need to read questions carefully before responding.

(d) (i) Endocytosis was given by many. Candidates had to use the information in the question stem and deduce that endocytosis occurs because the weakened pathogens would be too large to cross the cell surface membrane using any other method.

(ii) This question required candidates to apply their understanding of the role of antigen presentation in the triggering of an immune response. The strongest responses were able to do this by suggesting immune responses such as phagocytosis of the tumour cells or destruction of tumour cells by T-killer cells. Weaker answers simply repeated the question without giving any detail of this response, for example stating that an immune response occurs that destroys the tumour cells. Some candidates gained credit for using knowledge of the humoral immune response to suggest a role for antibody production in the destruction of the cancer cells. The weakest responses made reference to the destruction of a pathogen rather than applying their understanding to recognise that the tumour cells would be destroyed by the immune response.

Question 4

(a) (i) The majority of candidates answered this question correctly. Common incorrect responses included hydrogen bond, ester bond and peptide bond.

(ii) Candidates needed to use the diagram of the disaccharide sucrose as a starting point to answer this question. Some took great care to accurately complete the diagram to show the two separate monosaccharides produced as a result of the hydrolysis reaction, taking into account the addition of a molecule of water. It was quite common for candidates to draw the products inaccurately, with elements such as hydrogen missing from one or both monosaccharides. A proportion of candidates omitted to include a water molecule as a reactant in the hydrolysis of sucrose or suggested that water is a product of the reaction. Candidates who labelled the monomers accurately gained credit for showing their knowledge of these monosaccharides. Some candidates simply drew the whole sucrose molecule, suggesting a lack of understanding of a hydrolysis reaction.

(b) (i) Some candidates were able to use their knowledge of the structure of phloem sieve tubes to identify the sieve plate. Some wrote 'sieve', which was not credited. Weaker responses stated 'phloem' or 'sieve tube element'.

(ii) To answer this question accurately, candidates had to analyse the data in **Table 4.1** which showed the results of an unfamiliar investigation. Many candidates were able to describe the trend in the data effectively and link it to removal of phloem tissue. Fewer candidates were able to develop more detail in their answer and of these, some were able to deduce that phloem sieve tubes were removed as these are used to transport carbohydrate. A few candidates noticed the steep decrease in the mass of carbohydrate transported as the outer stem tissue removed increased from 90% to 100%, and were credited for a valid reason why this might have happened, such as most of the phloem sieve tubes being found in the inner part of the outer stem. Some candidates used the information in **Fig. 4.3**, which showed the location of the xylem tissue, to deduce that xylem was not removed during the experiment and so did not transport carbohydrate.

(c) Generally, there was a good understanding of the effect of a deletion mutation on the structure of a protein. Most candidates were able to state one effect, such as a change in primary or tertiary structure of the protein. Some candidates were able to take this idea further and link it to the function of the enzyme, such as a change in the shape of the active site. Weaker answers made reference to amino acids in the protein not being produced rather than correctly describing that amino acids would not be added to the chain. The strongest answers correctly described the effect of the mutation on the DNA; weaker responses made reference to the loss of a base rather than the loss of a nucleotide. Some answers were too imprecise to be credited, for example, describing 'a missing part to a gene'.

Question 5

(a) (i) The percentage decrease in the time taken for milk to become transparent when the concentration of trypsin increased from 0.25% to 0.5% was calculated correctly by some candidates. Other responses needed to recognise that the data for the calculation had to be taken from **Fig. 5.1**. A

common mistake was to attempt to use the percentages given in the question in the calculation, rather than the time taken for the milk to become transparent.

(ii) This question required candidates to carry out data analysis of the data in **Fig. 5.1** and then draw conclusions from that data using knowledge of enzymes. Most were able to identify that as the concentration of trypsin increased the number of active sites increased. Some expanded this idea, linking it to the formation of more enzyme-substrate complexes per unit time or the breakdown of more casein. A common incorrect idea was to link the plateau seen at high enzyme concentrations to the idea that substrate molecule concentration had reduced at the end of a reaction, rather than to the idea that substrate concentration was now the limiting factor. Many candidates started this question with a description of the trend in the data shown in **Fig. 5.1**. They were not able to gain credit for this as the command word for the question was 'explain' and not 'describe'.

(b) (i) To answer this question successfully, candidates had to apply their understanding of the advantages of immobilising an enzyme to the investigation outlined in the question. The most common correct idea was to state that immobilisation had changed the optimum temperature of the enzyme. Strong responses suggested a reason why the optimum temperature had changed, such as a change in the tertiary structure when the enzyme was immobilised.

(ii) Candidates found this question more straightforward than **Question 5(b)(i)**, and most were able to suggest that the enzyme free in solution may have denatured. Fewer candidates went on to explain why the immobilised enzyme had not denatured. The most common correct suggestions were the idea that immobilisation protects the enzyme and the idea that immobilisation reduces the kinetic energy of the enzyme.

Question 6

(a) The majority of candidates were able to identify a structure in **Fig. 6.1** that contains DNA. Some candidates who did well in the rest of the paper did not answer this question, highlighting the importance of checking carefully that all parts of the examination paper have been answered.

(b) This question was answered correctly by the majority of candidates, who were able to identify the phase of mitosis as anaphase. The most common incorrect answers were metaphase and telophase.

(c) Stronger candidates were able to apply their understanding of mitosis and the role of the spindle fibres in the stages of mitosis to consider an unfamiliar scenario of a cell in mitosis that has been treated with colchicine. These responses made the link between the microtubules mentioned in the question stem and the spindle fibres visible in **Fig. 6.1** to deduce that colchicine treatment would not have allowed the cell to pass through prophase and metaphase to reach the anaphase stage of mitosis. The details given linking chromosome behaviour to the role of the spindle were well expressed in these answers.

BIOLOGY

Paper 9700/22
AS Level Structured Questions 22

Key messages

Question 4(g) highlighted that candidates need to have a clear understanding of the difference between an antigen and a body cell. Some candidates used the term self antigen to equate to a whole body cell, rather than show an understanding that self antigens occur on the surface of body cells. This meant that answers included phrases such as 'so the T-lymphocytes will kill the self antigen' or 'phagocytosis of the antigen will occur', which did not gain credit.

Candidates should remind themselves of any introductory information that has been given to help them answer a question. In **Question 5(b)**, candidates were provided with details of the experiment that allowed **Fig. 5.1** to be constructed. This involved a solution of haemoglobin through which oxygen was bubbled. When answering **Question 5(b)(i)** it was evident that many candidates were visualising events occurring in the body and based their answer on enzymes rather than haemoglobin.

Question 6(a) partly assessed the transport of water in the root by the apoplast pathway. Although a large proportion of candidates described the passage of water through the cell walls of the cells in root tissue until the endodermis, a number incorrectly used the term osmosis to describe the mechanism of movement. For example, it was common to see descriptions such as 'water moves by osmosis down the water potential gradient'. Candidates should understand that when osmosis is used to describe the transport of water, it will mean that a partially permeable membrane is involved and so will contradict the fact that water does not cross any membranes in the apoplast pathway.

General comments

Many candidates gave comprehensive answers to questions requiring application of knowledge and understanding. They coped very well with the unfamiliar material presented and were careful to choose and organise, the relevant syllabus knowledge required.

Generally, candidates took note when the question included more than one command term or instruction and attempted to address the entire question. Scientific terms were used appropriately and spellings were usually correct. A greater use of scientific terminology would have greatly improved the quality of response for some candidates and there were occasions when the answer was in the right area of the syllabus but the level was not high enough to be awarded credit.

Candidates should concentrate on giving a full answer based on the question asked. This will include the main syllabus points that are required and can include more detailed relevant information, for example knowledge gained by a candidate from background reading. Candidates should save time and avoid providing extra information that has some connection to the subject matter but which is not relevant to the question. For example, in **Question 6(a)** some candidates wrote about the symplast pathway in addition to the apoplast pathway.

In **Question 3(b)**, candidates were invited to add labels and annotations to **Fig. 3.1**. There were many who did this very accurately and who gained full credit without having to use additional time by giving a written description.

Comments on specific questions

Question 1

(a) (i) Most candidates completed the **C:D column** in **Table 1.1** correctly.

(ii) The majority of candidates drew a circle around palmitic acid and stearic acid only. Some circled the column headed 'chemical structure'.

(iii) The majority of candidates who knew what was represented by **X** stated the term carboxylic acid or COOH. The wide range of incorrect answers included oxygen, glycerol and CH_3.

(iv) Candidates who gained full credit for this answer frequently explained that the fatty acids used to form the triglycerides could be of different lengths or could be saturated or unsaturated. Fewer introduced their answer by stating that triglycerides have three fatty acids (fatty acid residues) and very few explained that a fatty acid could be located in a different position on the molecule. It was also rare to see any of the other explanations. Credit could not always be given if candidates did not include reference to fatty acids and used 'they' instead or only referred to triglycerides and/or olive oils.

(b) There were some accurate answers to explain why water is a good solvent for substances such as glycerol but a poor solvent for substances such as triglycerides. The strongest responses included the fact that water is a dipolar (or polar) molecule. Further qualification was required for statements that glycerol is polar or that triglycerides are non-polar. Many knew that glycerol could form hydrogen bonds with water, whereas triglycerides could not. The terms hydrophilic and hydrophobic were used correctly to describe the interaction with water for glycerol or the lack of interaction by triglycerides respectively. Common errors were to confuse triglyceride structure or glycerol structure with phospholipid structure, so that the two molecules were described as having hydrophilic heads and hydrophobic tails.

(c) Sieve element was accepted instead of (phloem) sieve tube element, but phloem element was not. Sieve tube is not a type of cell but is the vessel composed of sieve tube elements, so this answer was not creditworthy. The most common incorrect answer was companion cell.

Question 2

(a) Many candidates chose to outline two effective and direct control methods that can be used to reduce transmission of the human immunodeficiency virus. Some answers were not precise enough to gain credit, such as 'sterilise equipment' or 'don't use syringes' or 'take the prescribed medicine'. Although instructions were given not to include ART as a control method, some candidates did use this method as one of their examples. A method such as contact tracing was not credited unless it was qualified with the idea of giving post-exposure prophylaxis to reduce the chance of viral transmission. Similarly, testing for HIV infection was not creditworthy unless further qualified with how transmission of the virus could be reduced if the person was infected. Incorrect responses included incorrect methods such as vaccination or an extreme measure, such as isolating infected people.

(b) There were numerous ways to give an acceptable definition of magnification. The quality of answer was very varied, with many candidates giving an accurate definition. Others gave a weaker response and gained credit by stating the formula used to calculate magnification. Terms such as 'zoomed' were not given credit. Weaker candidates gave a definition that included the need to use a microscope or gave part of the definition of resolution.

(c) (i) Overall, a greater proportion of candidates than in previous sessions knew that bacterial cell walls are composed of peptidoglycan (or murein). Only a small number named cellulose as part of the structure of the cell wall of bacteria or stated that bacteria did not have cell walls. The weakest responses did not include any feature related to the cell wall and stated other structural features characteristic only of a prokaryote, such as 'have only 70S ribosomes'.

(ii) The first two columns of **Table 2.1** were completed correctly by the majority of candidates. Some candidates suggested protein and lipid synthesis for the smooth endoplasmic reticulum (SER), and this did not gain credit. A very small number used knowledge not required for the AS syllabus to state detoxication. Fewer were able to gain the credit for correctly completing the final column of

the table. For this column, the most common incorrect concept was that mitochondria are present in bacterial cells.

(d) (i) The information given in the introduction to this question was essential in helping candidates organise their thoughts to arrive at the correct answer. There were some candidates who realised that adherence required binding of the gpA glycoproteins of *P. jirovecii* to cell surface membrane receptors (or proteins or glycoproteins) of the alveolar cells. Some candidates went on to explain that binding required complementary shapes. Binding of gpA glycoproteins to ECM proteins with complementary shapes was also a way of gaining credit. Some candidates suggested how adherence could occur by bond formation. A few who used understanding of cell signalling and had described gpA binding to an alveolar cell surface receptor stated that the gpA could act as a ligand, which was creditworthy. Some stated that binding occurred between gpA glycoproteins and the alveolar cell or between gpA and the ECM, and this was too general to gain credit. However, a reference to complementary shapes was awarded credit. Many candidates would have benefited from re-reading the text carefully to realise that gpA glycoproteins were molecules associated with *P. jirovecii*. These candidates gave a response based on the incorrect concept that gpA glycoproteins bind to the cell surface of *P. jirovecii.*

(ii) Many responses displayed an understanding that the diffusion of oxygen from the alveolar space into the alveolar capillaries would be impaired during a severe *P. jirovecii* infection. To gain full credit, some of the stronger answers related this to the colonisation by the pathogen and explained that a severe infection would mean that *P. jiovecii* cells would be covering much of the squamous epithelium, and/or they went on to explain that less oxygen diffusing into the capillary resulted in less oxygen being taken up by haemoglobin in the red blood cells. Other ways of gaining full credit were to explain how infection of the ECM would affect the role of the elastic fibres or collagen in gas exchange. Some candidates could have made it clearer that oxygen diffused into the capillaries; in these cases, they described diffusion of oxygen as being 'between' the capillary and the alveolus. Candidates were expected to use the term diffusion to describe the mechanism of movement of oxygen from the alveolar space into the capillary.

(e) Candidates were generally successful in giving a full account of how caspofungin could affect the action of the enzyme 1, 3-β-D-glucan synthase. Only a small number of candidates mistakenly described competitive inhibition. Full credit could only be achieved by also explaining how the decrease in the synthesis of 1, 3-β-D-glucan would affect cell wall formation and cause the death of *P. jirovecii* cells. Some candidates would have benefited from re-reading their answer, because a common error was to write '1, 3-β-D-glucan' instead of 'substrate', with many also stating correctly that less 1, 3-β-D-glucan was produced as a result of the inhibition.

Question 3

(a) This question asked why **Fig. 3.1** does not include any phosphodiester bonds. Some candidates had detailed knowledge and gave a clear answer. Some more imprecise answers were credited for an implication that bond formation occurred between nucleotides on the same strand and others by making reference to a sugar-phosphate backbone.

(b) It was not essential to give a written response to this question. Many candidates chose only to label and annotate **Fig. 3.1** and were able to gain full credit. Most answers gave the correct spellings of the named bases to gain credit. If **Fig. 3.1** had no labels, then candidates needed to make it clear which base was guanine and which base was cytosine. In addition, it was not acceptable to state that there was a purine and a pyrimidine in the base pair: these had to be identified by, for example, matching purine to guanine or by stating that it was the double-ringed structure. Written responses also needed to state that there were three hydrogen bonds between the complementary bases. Phosphate was frequently omitted from a response, but if the other components were identified, then full credit was still possible. Weaker responses gave a choice of the base pair, A-U and G-C, or identified the base pair as A-U by incorrectly matching these with 3 hydrogen bonds.

Question 4

(a) The majority of candidates gave a precise explanation of 'repair of tissues'. There were fewer candidates than in previous sessions who incorrectly stated that cells were repaired or regenerated. The most common incomplete response was to state that new cells are produced to repair tissues without explaining that cells that are old, damaged or worn out need to be replaced. Weaker responses implied that whole tissues are damaged and need to be replaced.

(b) Collectively, all the features of tumour formation from a fully differentiated cell were seen in responses. Some candidates were knowledgeable about the formation of oncogenes (from proto-oncogenes) and loss of activity of tumour suppressor genes. A number incorrectly wrote about proto-oncogene formation from oncogenes. A number of candidates stated that the differentiated cell would become undifferentiated and needed to go on to explain that the cell would lose its (original) function. Some used additional non-syllabus knowledge to write about cancerous tumours and metastasis. A proportion of these implied that the whole tumour was involved and should instead have explained that tumour cells break off and travel in the circulatory system to become established elsewhere in the body. Some weaker responses repeated information in the question introduction and stated that there is uncontrolled cell division, which did not gain credit.

(c) There were some candidates who showed an understanding that adult stem cells need to be able to carry out mitosis for a long time and that meant that DNA replication and mitosis needed to be carried out many times. Using the term 'longer' or 'more' in this instance does not have the same strength of meaning as 'long' and 'many'. Stronger responses explained that telomeres are non-coding sequences at the ends of chromosomes. Other responses did not explain the location of telomeres or described telomeres as 'non-coding genes'. There were a number of candidates who wrote about telomeres protecting the ends of chromosomes and a small proportion of these gave details as to why the mechanism of DNA replication requires the presence of telomeres. Some responses stated that telomeres prevent DNA from getting too short and did not qualify this further. Weaker responses described telomeres as containing repeated genes, or that they prevent the loss of too many genes.

(d) Many responses used **Fig. 4.1** to identify that GMP cells as progenitor cells were unable to carry out self-renewal, whereas this was possible with HSCs. Fewer realised that this meant that GMP cells could be described as having started to become differentiated. A large number of candidates used the diagram to correctly explain that GMP cells (only) could form neutrophils and monocytes. Further credit was gained by a smaller proportion of candidates who compared this situation to the fact that HSCs could produce all types of blood cells; it was not enough to state that they could produce all types of cells.

(e) Most knew that monocytes differentiate into macrophages to correctly identify cell type **X**. Mature monocytes, phagocytes and white blood cells were not sufficient to gain credit.

(f) Most candidates identified the molecules released by cell type **Y** as antibodies. A few stated immunoglobulins, which was also acceptable. A number of candidates identified cell type **Y**, which was not required, and stated 'plasma cells'.

(g) The most complete responses showed understanding that destruction of T-lymphocytes that bind to self antigens needed to take place in the thymus because once they were released in the general circulation then self-cells would be at risk of initiating an unwanted immune response. Many thought that self antigens meant self-cells, which meant that some or all of the response did not match the points that could gain credit. Some candidates gave an account of the role of T-lymphocytes and could have improved their response by clearly relating this to the example of the abnormal T-lymphocytes and the need to destroy them. A proportion of candidates gained credit for noting that the T-lymphocytes could otherwise cause an autoimmune disease. This was not required knowledge to gain full credit, but was credited where it was seen.

Question 5

(a) The three correct answers were *ovale* or *malariae*, which are listed in the syllabus learning outcome, and *knowlesi*, which some candidates stated using their additional knowledge. Spellings of these needed to be correct to gain credit. Incorrect responses, other than those with incorrect spellings such as ovare, ova and malaria, included cholera, anopheles, mosquito and bacterium.

(b) (i) Some candidates correctly understood this was an experiment using oxygen bubbled through a solution of haemoglobin. A proportion of these realised that they could not extrapolate from enzyme experiments and describe 'optimum' conditions for the scientists to consider and suggested that standardised conditions for temperature and pH needed to simulate the conditions occurring in the body. Fewer gave acceptable temperatures for body temperature and plasma pH, and some of those that did not succeed here, still gained full credit by showing an awareness that the action of haemoglobin could be affected by these two conditions. Some incorrectly focused their response on events occurring within red blood cells and wrote about optimum conditions for carbonic anhydrase or just stated 'enzymes'.

(ii) The strongest responses showed an understanding that the shift to the right of the oxygen dissociation curve was owing to malaria and so avoided reference to carbon dioxide and the Bohr shift. Many candidates could use **Fig. 5.1** to state that in the lungs the percentage saturation of haemoglobin would be lower and explain this in terms of a lowering of the affinity of haemoglobin for oxygen. Fewer made the deduction that the decrease in affinity would cause oxygen to dissociate from haemoglobin more easily in the respiring tissues.

(c) This was an extended response that was well answered by many candidates, with some giving more points than required to gain full credit. A common error was to state that the diameter of a red blood cell was 7 nm rather than 7 µm. The biconcave disc shape of a red blood cell was well known and some candidates could have been clearer about how this related to the function of the red blood cell, for example stating that this increased the surface area for the uptake of oxygen into the cell, rather than stating that the surface area increased so that oxygen could bind. Some candidates did not stay focused and gave one or two correct points and then continued to write about a red blood cell as if it were a molecule of haemoglobin. Here, for example, candidates described the red blood cell as being able to carry four oxygen molecules. A small number of candidates suggested how the red blood cell would change if it was infected, which was not answering the question posed.

Question 6

(a) For this question most candidates stated the involvement of cell walls. The most common misconception was to state that water moved by osmosis across the root or that water entered root hair cells by osmosis and then exited to enter the cell wall pathway. The strongest responses showed understanding that water is able to move to the xylem owing to the water potential gradient that is set up and avoided using the term osmosis because this would imply movement across a partially permeable membrane. 'Intracellular spaces' was frequently stated instead of 'intercellular spaces'. The presence of the Casparian strip composed of suberin in endodermal cells was well known. Candidates should know the correct spelling of 'Casparian' and 'suberin'.

(b) **Table 6.1** was completed correctly by many candidates. Where only partial credit was given, this was usually where candidates did not know that potassium ions moving down the concentration gradient would need to pass across the membrane by facilitated diffusion using a membrane protein.

BIOLOGY

Paper 9700/23
AS Level Structured Questions 23

Key messages

Questions may contain information that is a mix of the familiar and the unfamiliar. It is essential that candidates read and assimilate the text and any accompanying diagrams, photographs or data before reading the questions that follow. Some candidates needed to pay closer attention to the instructions in the questions to make full use of the information in their answers.

Many candidates need to be more confident of their vocabulary and spellings of scientific terms. A number used a scientific term that was vaguely similar phonetically or in spelling to the answer required but had a very different biological meaning. For example, in **Question 5(a)(ii)** candidates used 'cytokinins' 'cytokinesis' and 'cytosine' instead of 'cytokines'. Some candidates were unsure of the correct term to choose in **Question 3(b)** and **Question3(c)**, where there was confusion between nucleotides and bases, and between nucleic acids and nucleotides.

In the AS syllabus, it is acceptable to use the acronyms DNA, RNA and ATP instead of the longer full name of the molecules. For other scientific terms, it is good practice when giving a response for candidates to write out the full term the first time it is used, before they shorten the term by using acronyms, abbreviations or symbols. An example was the use of RA, LA and AV valve in **Question 1(b)** instead of right atrium, left atrium and atrioventricular valve. These were only acceptable where the candidate had given the full terms within the response to show that they had the correct knowledge.

General comments

Candidates had difficulties in assimilating the information given in several of the questions. Candidates should take care to read the information provided as this will guide them in the choice of syllabus material to use in their answers. Many candidates, for example, wrote about DNA replication in general in answer to **Question 3(b)** instead of describing what happens to the activated nucleotide shown in **Fig. 3.3**. Many answers began with the role of DNA helicase in unwinding the double helix by breaking the hydrogen bonds, even though it is clear from the diagram that this has already happened. Many also contrasted the action of the leading strand (shown in **Fig. 3.3**) with that of the lagging strand (not shown in **Fig. 3.3**). Answers to **Question 2(c)** often revealed many misunderstandings about the roles of organelles in animal cells.

Reading the whole paper or at least all the parts of a question before starting to answer may help candidates avoid writing the same answer to two different questions as sometimes occurred in **Question 3(b)** and **Question 3(c)**. Some of the words or terms required in answers are very specific and to be credited these need to be complete and need to be discerned from similar terms. This includes writing clearly a term that appears in a question. An example of this occurred with 'centromeres' in **Question 2(b)**. Sometimes 'centr…' could be discerned and then it was unclear whether the completed word was centriole, centromere or centrosome. Use of the appropriate scientific words is important. It was not uncommon to find 'moles' being used instead of molecules. In both **Question 1(a)(iii)** and **Question 6(b)(v)**, candidates wrote about cell walls. 'Walls made of thin cells' and 'alveolar walls' were acceptable, but the use of 'cell walls' is appropriate only for plants, bacteria and fungi, not animal cells as in these two questions.

Many candidates were confused between the directions 5' to 3' and 3' to 5' in **Question 3(c)** when describing the consequences of the antiparallel arrangement of the strands in DNA. Candidates who used the terms leading strand and lagging strand generally gained more credit.

Questions that ask for descriptions or explanations can rarely be answered effectively with very short list-style bullet points. Candidates who prefer to use bullet points to make the content of their response clearer,

particularly in extended answers, need to organise their ideas first and then use a sentence for each bullet point.

Comments on specific questions

Question 1

(a) (i) Many candidates correctly gave **B** and **C** as the parts of the gas exchange system that contain cartilage. **A**, the larynx was also accepted as an additional part. It was not correct to include **D** as this represented bronchioles that do not contain cartilage in their walls. If the correct letters were included in a longer list of letters, candidates did not gain credit. The instruction asked for the letters from **Fig. 1.1** to be identified and names of parts were ignored.

(ii) Almost all candidates stated that cartilage acts as support for the trachea and/or bronchus, so preventing the collapse of these airways. A few candidates realised that this tissue also allows flexibility.

(iii) Many candidates identified the region of the gas exchange system shown in **Fig. 1.2** as **G** and the region shown in **Fig. 1.3** as **B**. **C** and **A** were also accepted for **Fig. 1.3**. The final two columns of **Table 1.1** for **Fig 1.2** and **Fig 1.3** had to be completed so that the feature stated in column 2 was given a correct function in the final column. For **Fig. 1.2**, some candidates related the air spaces with providing a large surface area for gas exchange, while others noted that the squamous epithelium lining the alveoli was thin and provided a short diffusion distance for the respiratory gases. Some candidates identified the presence of capillaries and/or red blood cells, stating that they are for gas exchange or the absorption and/or transport of oxygen. Answers that were not accepted included stating that the air spaces provide a large surface area to volume ratio and that thin alveolar walls sped up diffusion.

There were proportionately more candidates who gained credit for a feature visible in **Fig. 1.3**, and these responses identified goblet cells and ciliated epithelial cells or ciliated epithelium or cilia. The roles of goblet cells and cilia were known, although some omitted to state that cilia move mucus. Weak responses stated that cilia trap or move pathogens, dust, etc. Some stated 'thin membrane'. Candidates should avoid using the term 'membrane' to describe a single cell layer of epithelium or endothelium.

Some candidates correctly identified **G** for **Fig. 1.2**, which was the label to the alveoli, and then repeated that the feature visible was 'alveoli'. If the correct identification (e.g. air spaces) was given in the final column along with the function, candidates were still credited for a visible feature and one way in which the feature related to function. There were a few candidates who gave a feature that was not visible in **Fig. 1.2** or **Fig 1.3**, such as cartilage, elastic fibres or smooth muscle, so credit was not given.

(b) Strong answers to this question paid attention to the instruction to describe a sequence and made it clear from the start that deoxygenated blood returns to the right atrium of the heart. The relevant valve between the right atrium and right ventricle was correctly identified (tricuspid valve or right atrioventricular valve) and an understanding was shown that when the right ventricle contracts the right atrioventricular valve closes to prevent backflow and the pulmonary (semi-lunar) valve opens so that blood enters the pulmonary arteries and flows to the lungs. Many candidates needed to make it clear that events were occurring in the right side of the heart and/or were imprecise about the valves, either omitting to name them or give details about the opening and closing of valves.

Stronger responses gave points about the coordination of the cardiac cycle by the sinoatrial node (SAN), the atrioventricular node (AVN) and the Purkyne tissue. The bundle of His was often mentioned. Some candidates who gave details about the SAN and AVN could have improved by including these points in appropriate places in the sequence of events during the cardiac cycle. Very few gained the credit available for impulses travelling across the muscle in the atrial walls. Some candidates referred to 'signals' being sent from the SAN rather than electrical impulses or waves of depolarisation. Very weak answers described the circulation of blood through the heart and lungs and/or through the systemic circulation without any reference to the contraction of the atria and ventricles or the action of valves. Others wrote about the flow of blood through the lungs and about the advantages of a double circulatory system. Some candidates incorrectly stated that deoxygenated blood returns to the heart in the pulmonary veins, rather than in the vena cava.

Question 2

(a) (i) There were many good answers to this question on stem cells. Many candidates stated that they are required to replace worn-out or dead cells and/or to repair damaged tissues. Some candidates stated incorrectly that they can be used to repair cells. A common answer was to state that stem cells can differentiate into specialised cells; this did not gain any credit unless preceded by the statement that stem cells must first divide to give rise to daughter cells that become specialised. Very few candidates explained that stem cells also divide to produce more stem cells to maintain the number in each tissue for future cell replacement. Some candidates realised that epithelial cells in the small intestine will need to be replaced regularly as they are exposed to much movement of food and to enzymes that increase the chance of damage.

(ii) Almost all candidates gave the stage of mitosis shown in cell **X** as anaphase. A few gave metaphase, which was not accepted.

(iii) Many candidates stated the part of the cell cycle as cytokinesis. Telophase was the most common incorrect answer.

(b) Most candidates knew that centromeres join together chromatids. To gain the credit, this needed to be qualified with identical, or sister chromatids. Many answers also correctly stated that spindle fibres or spindle microtubules are attached to the centromere of a chromosome. Some candidates referred to the kinetochore. This is not required knowledge for this syllabus and was credited if used in the correct context. Some candidates gained credit by stating that the centromeres divide or separate at the start of anaphase; a few went on to say that as a result the daughter chromosomes are moved to the poles by the shortening of spindle fibres. This last point had to be linked to the idea of division of the centromere, so did not gain credit if given on its own. Some candidates read the question as being about centrioles or centrosomes rather than about centromeres and so did not gain any credit.

(c) A number of candidates interpreted the information provided in the stem of the question and in **Fig. 2.2** to write excellent answers, including a suitable function for each cell and an explanation of how the structure of each cell is related to its function. Other candidates needed to assimilate the information provided, which included a reminder that the cells were specialised cells from the small intestine and look more carefully at the cell structures that were visible. These candidates needed to observe a specific feature or organelle, decide its role within the cell and link this to the overall function of the cell. There were many good answers for cell **P** and cell **R** and fewer for cell **Q**. Some candidates left this question blank.

Cell **P** is a columnar epithelial cell that has many microvilli on its luminal surface. A number of candidates knew that a function of this type of cell is absorption of the products of digestion. The cell contains many mitochondria to provide energy for active transport. Some other functions were accepted, such as breakdown of food molecules that happens on the surface of the microvilli and the production of enzymes that are inserted into the cell surface membrane or are held on the surface of the microvilli. A very large number of candidates incorrectly identified the structures at the cell surface of **P** as cilia and wrote about movement of mucus towards the mouth. Some of those who identified the microvilli correctly stated that they increase the surface area of the cell available for absorption. The statement that the microvilli increase the surface area to volume ratio of the cell was less acceptable as an explanation but was given credit. The misidentification of the microvilli in cell **P** as cilia suggested that some candidates needed to be more familiar with cell types that have microvilli.

Some candidates noticed similar features of cell **Q**, which is a goblet cell, with goblet cells of the ciliated epithelium in the gas exchange system. Cell **Q** is filled with secretory vesicles containing mucin and functions to synthesise and secrete (release) mucin or mucus as a protection against mechanical damage and chemical damage to intestinal epithelial cells. The most obvious features visible are the Golgi body for modifying protein (by adding carbohydrate chains) and packaging mucin in vacuoles. Some candidates thought that the cell was taking in material by endocytosis and breaking it down, with a proportion of these stating that the cell was a phagocyte. Endocytosis was given by some of the candidates who identified cell **Q** as a goblet cell.

The function of cell **R** is to synthesise and secrete enzymes or other proteins. The cell contains a large quantity of rough endoplasmic reticulum for protein synthesis. It also contains secretory

vesicles for the transport of protein to the cell surface membrane. Some candidates incorrectly referred to the enzyme being in lysosomes rather than vesicles.

Some candidates gave the function of cell **Q** and/or cell **R** as 'release of vesicles' rather than stating that the contents of the secretory vesicles are released at the cell surface. Some candidates incorrectly used the term endocytosis for the release of vesicles or exocytosis for the uptake of material by the formation of vesicles.

Question 3

(a) (i) A large number of candidates identified the type of base that includes U, T and C as pyrimidine. This was generally spelled correctly. The most common misspelling was 'pyramidine'. Some candidates gave purine as the answer.

(ii) Most candidates stated that DNA and RNA have four bases each. Many gained the credit here by stating that DNA has ATCG and RNA has AUCG or that DNA has thymine and RNA has uracil. To gain credit, candidates should have referred to both types of nucleic acid.

(b) It was important to assimilate all the information provided in **Fig. 3.1**, **Fig. 3.2** and **Fig. 3.3** before describing the sequence of events that occurs at the stage shown in **Fig. 3.3** to extend the strand being synthesised. Although many candidates did this, others needed to pay close enough attention to the instruction and produced responses that also contained information from **Fig. 3.2**. For example, some used additional knowledge to mention helicase and primase, while others ended their answers by writing about the leading strand and the lagging strand and the role of DNA ligase. The points credited in this question were those describing what happens to the activated (or free) nucleotide as it becomes incorporated into the extending strand. Some candidates were able to gain full credit by describing the complementary base pairing shown in the diagram, or by giving one or two creditworthy points and continuing to describe the formation of a phosphodiester bond. Some gave a clear description of the reaction between the –OH group of deoxyribose on the extending strand and the phosphate of the nucleotide, with the release of two phosphate groups.

A common error was to use the term 'base' when the only appropriate term was 'nucleotide'. For example, when describing phosphodiester bond formation, some stated that the bond was formed between bases. Some described complementary base pairing in general terms and could have improved their response by describing the specific pairing (A to T) shown in the diagram. A common error was to state that DNA ligase forms the phosphodiester bond. Some candidates wrote about transcription and mRNA, having been given the information that this process was the replication of DNA.

(c) Generally, candidates were successful at answering this question on the antiparallel nature of DNA. Many stated that the strands were in opposite directions and many referred to 3′ and 5′ in their answer. Full credit was only given if there was a correct explanation of the meaning of antiparallel. It was not enough to state that the strands were in different directions. Some candidates stated that strand extension only occurs in the 5′ to 3′ direction, as DNA polymerase can only synthesise the strand in that direction. Some candidates wrote about the leading and lagging strands formed during replication, although not all used the terms 'leading' and 'lagging'. A number of responses included reference to Okazaki fragments that are formed on the lagging strand. Knowledge of the role of DNA ligase in joining the fragments (by phosphodiester bond formation) was also credited. As there are many ligase enzymes, DNA ligase rather than ligase needed to be stated.

Question 4

(a) A proportion of candidates correctly gave a response focusing on the mixture of the three enzymes. As with **Question 2(b)**, many candidates needed to take greater care to read and assimilate the information that provided the context for this question on enzymes. It was quite common to see answers that referred to finding the optimum temperature and pH for each enzyme, rather than the optimum temperature and pH for the mixture of the three enzymes. A number of candidates who referred to the enzyme mixture mentioned working out the optimum conditions rather than specifically referring to temperature and pH. Stronger responses included finding a suitable crop waste (often described as 'the substrate') for the enzyme mixture, determining suitable concentrations of the enzymes, finding out whether the enzymes will be effective if immobilised, and determining the rate of sugar production. A few responses included determining a suitable ratio

of enzyme mixture to substrate and finding out whether there are any inhibitors in the mixture. Some of those who mentioned inhibitors needed to refer to their presence in the mixture or in the crop waste to gain credit. A few candidates mentioned feedback inhibition and finding a way to pre-treat the waste by grinding it. Some candidates suggested carrying out the Benedict's test to see which enzyme produced the sugar, and others wrote about V_{max} and K_m. These points were not appropriate for this question.

(b) Candidates were expected to note the monomers β-glucose and amino acids identified in the reaction mixture and explain that the results showed that the cell walls of leaves of *Arabidopsis thaliana* contain cellulose and protein. A high proportion of candidates correctly deduced that the cell wall contained cellulose, linking this to the β-glucose, with fewer making the link between cell wall proteins and amino acids. The strongest responses also noted that the peptides and the short chains of β-glucose were found because hydrolysis was not complete. It was common to see reference to glycosidic bonds being broken and occasional references to β-1,4 glycosidic bonds were made. To gain credit, candidates also needed to state that peptide bonds were broken. Some who named the two types of bond explained that the enzymes used were cellulase and protease. Quite a few candidates thought that the protein originated from the wall of the fungus or that the enzymes had been hydrolysed or denatured. Some candidates mistakenly thought that peptides and amino acids were the result of the breakdown of collagen in the cell wall, while others answered a different question by describing the chemical tests that could be carried out to show that glucose and amino acids were present. There was some confusion over the term peptides and peptide bonds, and some candidates described peptides being formed due to the formation of peptide bonds.

Question 5

(a) (i) Almost all candidates identified the cells in **Fig. 5.1** as **U4**, T-helper cell and **V4**, T-killer cell. Accepted alternatives for the latter included T-cytotoxic cell and T-cytotoxic lymphocyte. The most common error was to give the two types of lymphocytes the wrong way round.

(ii) There were many good descriptions of the roles of the T-lymphocytes in a primary immune response. Candidates stated that T-helper cells release cytokines and gave an example of the role of cytokines, such as stimulating B-lymphocytes to divide by mitosis and develop into plasma cells or stimulating macrophages to carry out phagocytosis. Some candidates referred to phagocytes or white blood cells rather than specifically to macrophages. Descriptions of the role of T-killer cells were generally less accurate as many candidates stated that they attack or kill antigens or pathogens directly, rather than attaching to infected cells (as shown in **Fig. 5.1**) and releasing chemicals to kill these cells. A common misconception was that T-killer cells release antibodies to kill the cells. However, many candidates gave the correct mode of action and also named a suitable chemical, such as hydrogen peroxide. Many also wrote about the function of perforin in making holes in the cell surface membrane of an infected cell. Some candidates used extended knowledge to explain that pore formation by perforins allowed other chemicals, such as granzymes, to enter the infected cell and begin the process of cell lysis.

(b) This question used an unfamiliar context, the Global Polio Eradication Initiative, to assess candidate understanding of vaccination programmes. Many good answers were seen. These discussed a range of steps that must be taken by health authorities and avoided writing about one or two steps only in great detail, which some candidates did. Common points made included making the vaccine free and providing sufficient vaccine so the whole population can be vaccinated to give herd immunity. Education about the seriousness of the disease and the importance of the vaccination was often included, with a few candidates raising the issue of countering misinformation and disinformation. Simply stating that health authorities should 'raise awareness' without further qualification was not sufficient to gain credit. Some candidates also wrote about how health authorities should respond more generally to a pandemic of an infectious disease, and aspects such as social distancing were not given credit. There were many good descriptions of ring vaccination. It was also common for candidates to discuss the need for trained personnel to deliver the programme and the benefit of quarantining infected individuals. Some candidates described how vaccines stimulate active immunity, which was not relevant.

Question 6

(a) **Table 6.1**, showing features of a plant cell, a prokaryotic cell and a virus, was completed correctly by a high proportion of candidates. Most candidates gave peptidoglycan or murein as the cell wall component of a prokaryotic cell. Common errors included stating that prokaryotic cell walls are composed of cellulose or protein, that prokaryotic cells contain 80S and 70S ribosomes, and that viruses contain DNA and RNA rather than DNA or RNA.

(b) (i) Strong responses stated clearly that the source of a cholera outbreak would be contaminated drinking water or contaminated food. A number of responses were not sufficiently precise by only stating 'contaminated water'. A few candidates stated correctly that a source could be people already infected with cholera. Natural disasters, such as earthquakes and severe flooding, which may be followed by outbreaks of cholera were considered to be causes and not sources. Some candidates stated that sources of drinking water such as wells may be the source and these did not gain credit unless it was indicated that the water was contaminated.

(ii) Many candidates stated that the protein choleragen is composed of more than one polypeptide or has two or more polypeptides. It was not necessary to know the number of polypeptides forming a choleragen molecule, and some candidates either knew that there were six or used **Fig. 6.1** to deduce this. Some stated seven polypeptides, which was allowed as the diagram could have indicated this to candidates.

(iii) The correct answer to this question about the receptor for choleragen was glycolipid, and as the question did not ask for a structure visible in **Fig. 6.1**, glycoprotein was also accepted.

(iv) Almost all candidates stated that ATP is the phosphorylated nucleotide needed for the removal of chloride ions from the epithelial cells lining the intestine. Some candidates did not gain credit because they wrote 'adenine triphosphate' rather than adenosine triphosphate. Many gave the correct name and the acronym.

(v) There were many good answers to this question on the loss of water from intestinal epithelial cells following entry of choleragen. Many candidates stated that chloride ions entering the lumen of the intestine would decrease the water potential in the lumen. Some candidates attributed the decrease in water potential to the presence of choleragen in the lumen and needed to relate the lower water potential to the presence of the chloride ions that had left the epithelial cells. To gain full credit, candidates needed to explain that water would leave the cell by osmosis or explain that water was moving down the water potential gradient. A common error was to state that water leaves the cell down 'a concentration gradient' and answers including this idea were not credited.

BIOLOGY

Paper 9700/31
Advanced Practical Skills 31

Key messages

Candidates should pay close attention to the wording of questions as this will indicate how the candidate should respond.

The word 'explain' may imply reasoning or some reference to theory, depending on the context. It is another way of asking candidates to 'give reasons for.' When the question states to 'explain the shape of the graph', the candidate needs to make sure that they give reasons as to why something happens, such as referring to the increase in concentration of lactose resulting in the formation of more enzyme-substrate complexes and the active sites becoming saturated.

General comments

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

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

Comments on specific questions

Question 1

(a) (i) Many candidates correctly completed **Fig. 1.1** by stating four starch-milk concentrations, 0.2%, 0.04%, 0.008% and 0.0016% under the beakers. They also showed the transfer of 2 cm^3 to each beaker from the previous beaker and showed 8 cm^3 of water added 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 starch-milk and the heading for colour score. The majority of candidates gained credit for stating results for each of the concentrations of starch-milk. The stronger candidates showed the correct trend in their results and used the colour score to record the colour of the solutions.

(iii) The majority of candidates correctly stated 1 cm^3 as the volume of **CM** to be used.

(iv) The majority of candidates correctly recorded the colour score for test-tube **CM**.

(v) Many candidates correctly determined the concentration of starch in the contaminated milk, **CM**, by referring to their results in **Question 1(a)(ii)** and **Question 1(a)(iv)**.

(vi) Many candidates correctly identified a source of error by stating that it was difficult to match the colour of the starch-milk solution with the colours set out in **Fig. 1.2**.

(vii) Some candidates correctly suggested that milk was used to dilute the starch-milk solution rather than water as water would dilute the colour and give a different result than if milk were used.

(viii) Many candidates correctly suggested that Benedict's solution could be used to determine the concentration of glucose in a sample of contaminated milk by heating a mixture of the milk with Benedict's solution to over 80 °C and measuring the time to the first colour change.

(b) (i) Most candidates correctly used the headings given in **Table 1.2** to correctly label the *x*-axis (concentration of lactose / mmol dm^{-3}) and the *y*-axis (rate of reaction / arbitrary units). Some candidates labelled the incorrect axis or gave incomplete headings. The stronger candidates, for the *x*-axis, used a scale of 40 to 2 cm and for the *y*-axis, used a scale of 0.25 or 0.2 to 2 cm. Many candidates plotted all the points accurately and joined the points with a thin line. The most common error was not using the correct scale for the *y*-axis.

(ii) Some candidates correctly stated that as the rate increased lactose concentration increased and then levelled off as there were more substrate molecules and more enzyme-substrate complexes formed. The stronger candidates also described that the rate of reaction levelled off because the active sites were saturated.

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 part of the leaf section on **J1**. Many candidates gained credit for drawing a definite bulge between the lamina and no cells were drawn. The stronger candidates drew the correct proportion of the palisade layer, showed the subdivision of the vascular bundle and 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 one other vessel element, drawn in a line and with double lines representing the cell walls. The stronger candidates drew cells that had more than four sides. The most common error was to draw lines that did not meet up precisely or were too thick. Most candidates used a label line to identify the wall of one xylem vessel element.

(b) (i) Many candidates were able to identify three observable differences between the section on **J1** and the section in **Fig. 2.2** such as there were fewer vascular bundles on **J1** than in **Fig. 2.2**, the palisade layer on **J1** was thicker than in **Fig. 2.2** and there were no trichomes on **J1** but trichomes were present in **Fig. 2.2**.

(ii) Many candidates correctly stated that there were 10 eyepiece graticule units in 0.2 mm and correctly stated that the length of one eyepiece graticule unit was 0.02 mm or 20 μm.

(iii) The majority of candidates correctly stated that there were 75 eyepiece graticule units across the width of the section and showed this number multiplied by the length of one eyepiece unit calculated in **Question 2(b)(ii)**.

BIOLOGY

Paper 9700/33
Advanced Practical Skills 33

Key messages

Candidates should pay close attention to the wording of questions as this will indicate how the candidate should respond.

Candidates may be asked to suggest improvements to the procedure and in this case were required to suggest two improvements to the investigation that would increase confidence in the results. The candidates needed to suggest using more concentrations of ethanol and to carry out repeats and calculate a mean. Stronger candidates suggested that the use of a gas syringe would increase confidence as it was a better way of measuring the volume of gas.

General comments

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

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

Comments on specific questions

Question 1

(a) (i) The majority of candidates identified a source of error as the difficulty of measuring the height of the foam.

(ii) Many candidates correctly completed **Fig. 1.2** by stating three ethanol concentrations, 50%, 25% and 12.5% under the beakers. They showed the transfer of 30 cm^3 to each beaker from the previous beaker and showed 30 cm^3 of water added to each of the three beakers.

(iii) The majority of candidates organised their results clearly by presenting a ruled table. The stronger candidates included the heading for percentage concentration of ethanol and the heading for height of foam with the appropriate units (mm). The majority of candidates gained credit for stating results for 0% concentration ethanol and results at 1 minute and at 2 minutes for all the concentrations of ethanol. The stronger candidates stated the correct trend and recorded the heights in whole millimetres.

(iv) Some candidates correctly showed how to calculate the rate at which foam was produced at 1 minute and at 2 minutes for 100% ethanol by dividing the height of foam by the time taken and stating the appropriate units, either as mm per minute or mm per second.

(v) Some candidates correctly described how the rate changed with times according to their results.

(vi) Some candidates correctly explained that the results of 0% ethanol were important as they showed the activity of catalase without ethanol.

(vii) The majority of candidates correctly stated that the dependent variable was the height of foam.

(viii) Many candidates correctly suggested two improvements such as using more concentrations of ethanol or carrying out repeats and calculating a mean. Stronger candidates correctly suggested that a gas syringe could be used to measure volume of gas.

(b) (i) Most candidates correctly used the headings given in **Table 1.2** to label the *x*-axis (concentration of ethanol / $\mu dm^3 dm^{-3}$) and the *y*-axis (PPO activity arbitrary units / au). Some candidates, however, labelled the incorrect axis or gave incomplete headings. The stronger candidates, for the *x*-axis, used a scale of 100 to 2 cm and for the *y*-axis, used a scale of 0.5 to 2 cm. Many candidates plotted all the points accurately and joined the points with a thin line. The most common error was not using the correct scale for the *y*-axis.

(ii) Many candidates correctly suggested an explanation for the pattern shown in the data by stating that as the concentration of ethanol increased, PPO activity decreased, that ethanol acts as an inhibitor, and at higher concentrations of ethanol fewer enzyme-substrate complexes were formed and PPO enzymes started to denature.

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 part of the stem section on **K1**. Many candidates gained credit for drawing at least four vascular bundles, drawing the layer beneath the epidermis and using a label line to correctly identify the 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 cells from the centre of the stem with each cell touching at least two of the other cells and with double lines representing the cell walls. The stronger candidates drew cells that had more than four sides. The most common error was to draw lines that did not meet up precisely or were too thick. Most candidates used a label line to identify the cell wall of one cell.

(b) (i) Many candidates correctly measured the length of each of the vascular bundles with the appropriate units and showed the five measurements added together and divided by 5 to calculate a mean. The more able candidates showed division by 12 and gave the mean actual length with the appropriate units.

(ii) Some candidates correctly described modifications to the method such as measuring all the vascular bundles and taking more sections from the whole plant.

(c) Many candidates were able to identify three observable differences between the stem section on **K1** and the stem section in **Fig. 2.3** such as there were more vascular bundles on **K1** than in **Fig. 2.3**, the vascular bundles on **K1** were spread out while those in **Fig. 2.3** were in a ring and there were trichomes on **K1** and none in **Fig. 2.3**.

BIOLOGY

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, in order to develop the skills that can be applied to the requirements of the exam.

Candidates demonstrated that they could follow instructions to skilfully carry out an investigation and record the results in an appropriate table. Candidates should assess their results carefully when estimating an unknown sample as the given concentration may not be one that they have chosen to make.

During the investigation candidates were able to identify how the procedure could be improved so that a more accurate estimate of the concentration of sugar in a carrot extract could be obtained. When using their estimate to give examples of appropriate concentrations that would improve the accuracy of the estimate, candidates should think carefully about the range of concentrations stated.

Candidates should remember that when drawing a graph, a linear scale should be chosen which allows the data to be plotted to half a square, and that this may mean that the axes start at a value other than 0.

Candidates should observe fine detail when viewing slides under a microscope or on a photomicrograph and include such detail when producing diagrams, such as the shapes of cells in high power diagrams and the proportion of the tissues in a plan diagram.

Candidates would benefit from practice using a scale bar to calculate the actual length of a structure shown on a photomicrograph.

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 need to read the whole of each question before attempting it so that they can plan their time carefully and answer the specific questions accurately.

Comments on specific questions

Question 1

(a) (i) The majority of candidates selected at least three additional concentrations of sugar solution between 1.0 mol dm^{-3} and 0 mol dm^{-3} stated in **Table 1.2** and completed the table with the correct volumes of **S** and **W** to prepare the concentrations. Some candidates incorrectly selected concentrations made by serial dilution instead of proportional dilution but then stated the correct volumes of **S** and **W** to prepare the additional concentrations, so were awarded credit for this. A few candidates incorrectly selected concentrations made by serial dilution and did not gain any credit as the volumes to make the stated concentrations were incorrect.

(ii) The majority of candidates organised their results clearly by presenting a ruled table and included the heading for concentration of sugar (**S**) and mol dm^{-3} and the heading for time and seconds. They gained credit for recording a time for all the concentrations of sugar solution made, and recorded results which showed that the time for the solution to become colourless for the highest

concentration of sugar was shorter than the time for the solution to become colourless for the lowest concentration of sugar. The majority of candidates gained credit for recording time in whole seconds. The most common error was not including the time for 0 mol dm^{-3} so these candidates were unable to gain credit for recording a result for each concentration of sugar solution tested.

(iii) Most candidates recorded the time to reach the end-point for **C** and included units.

(iv) Most candidates used their results from **Question 1(a)(ii)** and **Question 1(a)(iii)** to correctly estimate the concentration of sugar in carrot extract **C**. Some candidates did not consider that **C** may be between two of their chosen concentrations.

(v) Many candidates suggested how to modify the procedure to improve the accuracy of the estimate for the concentration of sugar in carrot extract **C**. Many candidates suggested repeating the experiment and calculating a mean or using a colorimeter. Some candidates correctly described plotting a graph and how to use the graph to estimate the concentration of sugar in carrot extract **C**. Most candidates suggested using concentrations with narrower intervals, with the stronger candidates using their estimate in **Question 1(a)(iv)** and stating examples of suitable concentrations to use both sides of the estimate for **C**. The most common error was to use the estimate in **Question 1(a)(iv)** as the upper or lower value in the suggested range of concentrations.

(vi) Some candidates correctly stated that the size or mass of the vegetable used to make the vegetable extract should be the same and some candidates stated that the volume of extract used in each experiment should be standardised.

(vii) Some candidates suggested using different concentrations of starch and a few correctly suggested using five different concentrations. Most candidates correctly stated iodine as the indicator used for detecting the presence of starch and some candidates suggested using a colorimeter to measure the intensity of colour, stating that the darker the intensity the higher the concentration of starch.

(b) (i) The majority of candidates drew the graph using the headings given in the table to correctly label mass of potassium manganate(VII) / g on the *x*-axis and mean post-harvest life / days on the *y*-axis. Some of the candidates used scales of 2 g to 2 cm for the *x*-axis and 1 day to 2 cm for the *y*-axis, starting at 9 days, and plotted the points exactly with a dot in a circle or a small cross. Many candidates drew a sharp, clear ruled line or a curve accurately connecting the points. The most common errors were using a scale of 3 days or 4 days to 2 cm on the *y*-axis so that the points could not be accurately plotted and drawing lines plot to plot that did not accurately connect the points.

(ii) Most of the candidates correctly used the graph to predict the post-harvest life of bananas if the mass of potassium manganate(VII) is 6.8 g and showed on the graph how this value was obtained.

(ii) Many candidates suggested why the post-harvest life of bananas decreases when more than 6 g of potassium manganate(VII) is used. Many candidates suggested that the water produced when ethylene gas is oxidised causes the banana cells to swell due to osmosis or that the increase in carbon dioxide alters the pH which may inhibit enzymes in the banana. Other suitable suggestions included: potassium manganate(VII) above 6.8 g is toxic to the bananas, encourages the growth of microorganisms, causes the skin to change colour and affects the flavour.

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 whole root. The stronger candidates gained credit for drawing the correct shape of the epidermis and for showing the correct proportion of the vascular tissue to the whole root. 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 which joined up precisely and used most of the space provided. Most candidates were able to draw a group of four adjacent cells, two cells from the epidermis and two cells from below the epidermis, with each cell touching at least two of the other cells and with double lines representing the cell walls. The stronger candidates showed the correct shapes of the cells. The majority of candidates used a label line to show the cell wall of one cell. The most common errors

were to draw lines that did not meet up precisely and to draw a group of four cells that did not resemble the two cells from the epidermis and two cells from below the epidermis of this root section.

(b) The majority of candidates identified three observable differences between the section on **L1** and the section in **Fig. 2.1** using only observable differences. Most candidates stated that there was one vascular bundle in the centre on **L1** and several vascular bundles were present around the edge of **Fig. 2.1**. Many candidates stated that **L1** had cells in the centre whereas in **Fig. 2.1** the centre was hollow or that the outline of **L1** was wavy and the outline of **Fig. 2.1** was round. Many candidates stated that the cortex was wider on **L1** than in **Fig. 2.1**. Credit was not awarded to candidates when structures that were not observable were included, for example, when the epidermis was referred to as the epithelium or the whole section was referred to as a cell.

(c) The majority of candidates correctly measured the diameter of the section using the length of the line **A–B** and showed the measurement with appropriate units. Many candidates also correctly measured the length of the scale bar using appropriate units. The stronger candidates showed the division of the measured length of line **A–B** by the measured length of the scale bar and then showed the answer multiplied by the actual length of the scale bar (525 μm). Many candidates correctly recorded the actual diameter of the section with the appropriate units. The most common error was not measuring the scale bar so the actual diameter of the section could not be calculated.

BIOLOGY

Paper 9700/35
Advanced Practical Skills 35

Key messages

Candidates demonstrated that they could skilfully carry out the investigation and record the results in an appropriate table.

Candidates should think carefully about the investigation they have carried out and apply their knowledge about the topic when explaining their results. The word 'explain' may imply reasoning or some reference to theory, depending on the context. When the question states 'Explain the results for **S1**, **S2** and **S3**', the candidate needs to make sure that they give reasons as to why starch or reducing sugar is present or absent in each solution, using their knowledge about enzymes and temperature.

Candidates should be aware of the difference between qualitative and quantitative results and be able to describe procedures to obtain qualitative or quantitative results.

Candidates should observe fine detail when viewing slides under a microscope or on a photomicrograph. They should include such detail when producing diagrams, for example, the presence of chloroplasts and the size and shape of cells in high power diagrams, and the shape and proportion of the tissues in a plan diagram.

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

Comments on specific questions

Question 1

(a) (i) Some candidates were able to explain that the test-tubes were left in the water-bath for 3 minutes before adding the starch solution to allow the contents in the test-tubes to reach the temperature of the water-bath. Many candidates incorrectly suggested that leaving the test-tubes in the water-bath for 3 minutes allowed the test-tubes to reach the temperature of the water-bath or that the solutions were left for 3 minutes as they needed to reach the optimum temperature for the enzyme.

(ii) The majority of candidates correctly stated Benedict's as the reagent used to test for reducing sugar. Most candidates described using a volume of Benedict's reagent equal to or greater than the volume of sample used and some candidates described using a boiling water-bath or stated a temperature of at least 80 °C. Some candidates correctly stated that the solution with the highest amount of reducing sugar would have the fastest time to the first colour change. The most common errors were to state the colours produced by the Benedict's test or the fastest time to reach brick red.

(iii) Some candidates correctly stated temperature as the independent variable.

(iv) The majority of candidates organised their results clearly by presenting a ruled table. A few candidates included the heading for temperature and °C. The majority of candidates included the heading time and seconds for the reducing sugar test and the heading colour for the starch test. They gained credit for recording a time for the reducing sugar test and a colour for the starch test for three samples (**S1**, **S2**, **S3**). The majority of candidates gained credit for recording time in whole seconds and including the correct colours for the starch test. A few candidates needed to record the colours for the starch test or they incorrectly recorded the colours from the reducing sugar test.

(v) The majority of candidates correctly completed **Table 1.2** with the appropriate words, using their results from **Question 1(a)(iv)**.

(vi) Some candidates used their results to explain that in **S2** all of the starch had been hydrolysed as the reaction had taken place at 40 °C, which was the optimum temperature for amylase, so many enzyme-substrate complexes were formed. Most candidates explained that as the investigation for **S3** had taken place at 100 °C, the enzyme had been denatured and so none of the starch had been hydrolysed and no enzyme-substrate complexes were formed. A few candidates explained that as the reaction in **S1** had taken place at 0 °C, the enzyme had little kinetic energy so the reaction happened slowly resulting in some of the starch being hydrolysed and only few enzyme-substrate complexes being formed. A few candidates explained that at 0 °C some starch had been hydrolysed, at 40 °C all the starch had been hydrolysed and at 100 °C none of the starch had been hydrolysed. The most common incorrect answer was to describe the reducing sugar and starch content in **S1**, **S2** and **S3**.

(vii) The majority of candidates recorded a time to first colour change for the reducing sugar test and a colour for the starch test, for **U**.

(viii) Most candidates used their results from **Question 1(a)(iv)** and **Question 1(a)(vii)** to correctly estimate the temperature used to produce the products of the reaction between starch and amylase in **U**.

(ix) Many candidates described using known concentrations of reducing sugar and some gained credit for stating five known concentrations of reducing sugar. Many responses described using the Benedict's test for the known concentrations of reducing sugar. Some candidates also stated using the Benedict's test for the unknown solution; these were not awarded credit as they described using colours to estimate the concentration of reducing sugar. Some candidates described comparing the colour of the unknown solution to the colours of the known concentrations to estimate the concentration of reducing sugar in the unknown solution and some candidates needed to state what they were comparing. A few candidates correctly described drawing a graph of time to first colour change for known reducing sugar concentrations and reading off the concentration of reducing sugar for the unknown solution.

(b) The majority of candidates drew the graph, using the headings given in the table to correctly label temperature / °C on the *x*-axis and rate of reaction / arbitrary units on the *y*-axis. Most of the candidates used scales of 5 °C to 2 cm for the *x*-axis, with 20 at the origin, and 20 arbitrary units to 2 cm for the *y*-axis, and plotted the points exactly with a dot in a circle or a small cross. Many candidates drew a sharp, clear ruled line or a curve accurately connecting the points. The most common errors were using a scale of 10 °C to 2 cm on the *x*-axis and drawing lines plot to plot that did not accurately connect the points.

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 whole leaf with a bulge above the midrib and pointed lamina. The stronger candidates gained credit for drawing two lines around the whole section for the epidermis, a palisade layer that curved upwards into the bulge and the correct shape of the vascular bundle. The majority of candidates used a label line to correctly identify the palisade tissue.

(ii) Credit was awarded to candidates whose drawings were made using a sharp pencil to produce thin continuous lines which joined up precisely and used most of the space provided. Most candidates were able to draw a group of four adjacent cells, two cells from the epidermis and two cells from

below the epidermis, with each cell touching at least two of the other cells and with double lines representing the cell walls. The stronger candidates showed the correct shape of the epidermal cells and the correct size of the epidermal cells relative to the cells beneath them. Some candidates drew a large number of chloroplasts in both cells beneath the epidermis and used a label line to label one chloroplast. The most common errors were to draw lines that did not meet up precisely and draw only one small circle to represent a chloroplast.

(b) The majority of candidates identified three observable differences between the section on **M1** and the section in **Fig. 2.1**. Many candidates identified a large bulge above the epidermis on **M1** and a smaller bulge in **Fig. 2.1**, and that **M1** had pointed leaf blades whereas the leaf blades in **Fig. 2.1** were more rounded. Many candidates stated that the vascular bundle on **M1** was elongated and in **Fig. 2.1** it was oval, and the circle of cells surrounding the vascular bundle contained smaller cells than that in **Fig. 2.1**. Credit was not awarded to candidates for structures that could not be observed or for identifying additional observable features.

(c) The majority of candidates correctly calculated the actual mean thickness of the leaf. They accurately measured the thickness of the leaf using the lines **P1**, **P2**, **P3**, **P4** and **P5** and included appropriate units. They showed the measurements of the lines divided by five to calculate the mean length of the lines and then the mean length of the lines divided by the magnification to calculate the actual mean thickness of the leaf.

BIOLOGY

Paper 9700/36
Advanced Practical Skills 36

Key messages

Candidates should pay close attention to the wording of questions as this will indicate how they should respond.

Candidates may be asked to suggest improvements to the procedure and in this case were required to identify a source of error and suggest a modification that would reduce the effect of that error. The candidates needed to state that judging the cloudiness was subjective and a modification was to remove human judgement by using a colorimeter.

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

Comments on specific questions

Question 1

(a) (i) Many candidates correctly completed **Table 1.2** by stating three concentrations of hydrochloric acid (e.g. 1.6 mol dm^{-3}, 1.2 mol dm^{-3} and 0.8 mol dm^{-3}), stating the correct volumes of hydrochloric acid for each concentration (e.g. 4 cm^3, 3 cm^3, 2 cm^3 and 1 cm^3) and stating the correct volume of water for each concentration (e.g. 1 cm^3, 2 cm^3, 3 cm^3 and 4 cm^3).

(ii) Many candidates correctly completed **Table 1.3** by stating three more descriptions of appearance such as 'cloudy', 'less cloudy' and 'nearly clear' and stated a key for each appearance such as: +++++, ++++, +++, ++ and +.

(iii) The majority of candidates organised their results clearly by presenting a ruled table. The stronger candidates included the heading for the concentration of hydrochloric acid with units (mol dm^{-3}) and the heading for cloudiness. The majority of candidates gained credit for stating an observation of cloudiness for each concentration using the key set out in **Table 1.3**. The results of the stronger candidates showed the correct trend for the results at 0 and 10 minutes.

(iv) Most candidates stated the correct pattern of results at 0 minutes by stating that as the concentration of hydrochloric acid decreased the solution became less cloudy.

(v) Some candidates correctly described the effect of the concentration of hydrochloric acid on the rate of precipitation by stating that the higher the concentration of hydrochloric acid, the faster the rate of precipitation and referred to their observations at 0, 5 and 10 minutes.

(vi) The majority of candidates completed **Table 1.4** by correctly stating that the type of error was systematic and that there was no effect on the trend at 0 minutes.

(vii) Many candidates correctly identified the source of error as the difficulty of judging the cloudiness and suggested that using a colorimeter was a suitable modification.

(b) (i) The majority of candidates drew a bar chart, using the headings given in the table, with 'protein in blood plasma' on the *x*-axis and 'percentage of total protein' on the *y*-axis.

The stronger candidates ensured that all five bars were the same width and used a scale for the *y*-axis of 10 to 2 cm. These candidates separated the bars and identified the bars using the headings in **Table 1.5**. Many candidates plotted the horizontal line at the top of each bar exactly with a thin line.

The most common errors were not including a full axis label for the *y*-axis, omitting the units for the *y*-axis and not labelling the scale every 2 cm, including the label at 60.

(ii) Many candidates correctly calculated the concentration of globulin proteins in the blood plasma by showing the addition of 12.5, 16.5 and 8.5, showing the multiplication by 70 and division by 100. The stronger candidates gave their answer to the appropriate number of significant figures.

Question 2

(a) (i) 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 starch grains, two grains from slide **C** and two grains from slide **D** and drew all the starch grains with surface patterns. The stronger candidates drew the correct surface pattern for the starch grains from slide **C** and the correct surface pattern for the starch grains from slide **D**.

(ii) The majority of candidates correctly stated that iodine solution was the reagent used to test for starch and that the correct colour produced if starch was present was blue-black.

(iii) Many candidates correctly suggested the reason why starch grains get smaller as plants germinate was that enzymes break down the starch in the grains to provide energy.

(b) (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 part of the leaf section on **N1**. Many candidates gained credit for drawing at least two vascular bundles and the correct shape of the leaf and using a label line to correctly identify a vascular bundle.

(ii) Many candidates were able to identify three observable differences between the section on **N1** and the stem section in **Fig. 2.2** such as there were more vascular bundles on **N1** than in **Fig. 2.2**, the vascular bundles on **N1** were in the middle while those in **Fig. 2.2** were nearer to the epidermis and there were many air spaces on **N1** and none in **Fig. 2.2**.

(iii) The majority of candidates correctly stated that there were 28 eyepiece graticule units across the width of the leaf. The stronger candidates showed the multiplication of 28 by 34 μm and gave the correct answer with the appropriate units.

BIOLOGY

Paper 9700/41
A Level Structured Questions 41

Key messages

The majority of candidates wrote clearly and presented creditable work. In a significant number of scripts, handwriting needed to be improved to ensure that responses could be deciphered and awarded all of the credit due.

There were a few whose answers regularly overflowed the answer space and continued down the side margins of the page. Candidates should plan their answer so that they make the same number of points as there are marks available, in a way that uses the amount of answer space provided.

General comments

Many candidates were well prepared and showed a thorough knowledge of the syllabus topics and well-trained skills in the analysis of data and interpretation of new contexts. The most successful answers were those that showed attention to detail and that were expressed clearly and logically. The most common areas for improvement that could have led to additional credit were reading the question more carefully and making sure to follow the question rubric. The areas of Biology where candidates showed most knowledge and understanding were nervous transmission (**Question 1**), stomatal opening (**Question 2**), respiration (**Question 3**) and using the Lincoln index (**Question 10(d)**). Questions involving inheritance and molecular genetics were found to be more challenging (**Questions 5, 7, 8** and **10(c)**). Correct and precise use of terminology is essential when thinking and writing about genetics and applications of knowledge of DNA.

Comments on specific questions

Question 1

(a) (i) Many candidates named two structures correctly, usually dendrites (**A**) and nuclei (**B**). For **C**, the label line pointed to the swollen end adjacent to the synapse and the specific term 'synaptic knob' was required, not the less specific 'axon terminal'. It should be noted that the synaptic knob is always before the synaptic cleft, i.e. presynaptic, and it is unnecessary and a mistake to name it as 'presynaptic knob'.

(ii) Most candidates answered this question correctly. Answers mostly identified the rat as having a myelinated axon or Schwann cells and made reference to or described saltatory conduction. Some candidates needed to specify which animal's neurone they were discussing; as the question referred to both, this needed to be made clear.

(b) The most successful candidates made use of the correct terms for describing parts of the action potential, e.g. depolarisation, repolarisation, the refractory period and hyperpolarisation. They made comparative points, read figures to within half a grid square from the graphs and specified which animal's neurone took longer for a certain stage to be completed or which animal's neurone reached a greater depolarisation at the peak of the action potential. Common errors were pointing out similarities although the question asked candidates to contrast and quoting figures without specifying exactly what these referred to by using the appropriate term. Weaker responses sometimes misused the term threshold potential when they meant the peak of depolarisation of the action potential.

Question 2

(a) Many candidates gave clear answers, specifying when stomata open and close over a 24-hour period and why. Weaker candidates needed to use the 24-hour period as a frame of reference for their discussion of what stomata do and why, although many stated that open stomata allowed carbon dioxide to enter for photosynthesis and that they closed to prevent water loss by transpiration.

(b) Overall, candidates performed very well on this question. Most noted the reference to guard cells in the question and framed their answer correctly in terms of movements of ions and water in and out of these cells, and not in and out of the pores themselves (stomata). Candidates generally showed detailed knowledge of the mechanism of stomatal opening. Few stated that the pumping of protons out of the guard cell results in the charge inside the cell membrane becoming more negative than before (as opposed to just negative, which is always the case). It was also rare for candidates to describe the thicker inner cell walls of a pair of guard cells and the thinner outer walls causing the cell to bend so that the stoma opened. A few candidates described the graph instead.

(c) This was a challenging question where candidates who had some understanding of the right idea found it hard to put these into words. The evidence for genetic control was the continuation of the 24-hour repeating pattern of opening and closing when the plant was kept in the dark. The evidence for a role for the environment was the peak number of open stomata decreasing over successive cycles in the absence of a daily light stimulus. The strongest candidates made both of these points.

Question 3

(a) Candidates were best at identifying covalent bond formation between coenzyme A and an acetyl group in the link reaction and in selecting the link reaction and Krebs' cycle as the stages that release carbon dioxide. The most common error in identifying which events occurred at different stages of aerobic respiration was thinking that catabolism happens in oxidative phosphorylation. Where candidates are asked to put ticks and crosses in a table, they must follow the rubric and not leave squares blank.

(b) (i) The majority of answers showed how RQ is calculated and gave the figures for carbohydrates and lipids. Most of these needed to go on to use the information from the question to explain that the air flow meter would measure the oxygen intake, and the carbon dioxide sensor would determine the concentration of carbon dioxide exhaled.

(ii) The majority selected lipids as having the higher energy value. Candidates frequently made reference to lipids having more hydrogen atoms or more carbon-hydrogen bonds and some went on to relate this to more reduced NAD forming, leading to a greater proton gradient. Common mistakes were to confuse energy value with RQ, to quote figures for energy content with the wrong unit (just kJ or kJ mol^{-1} instead of the correct kJ g^{-1}) and to write about lipids having more hydrogen molecules or more hydrogen bonds.

Question 4

(a) Candidates' recall of events that lead to shutting of the lobes of the Venus fly trap was an area in need of improvement. The most remembered point was the need for two sensory hairs to be touched, as opposed to the single touch trigger for the folding of the leaf in *Mimosa pudica*. Few candidates named the relevant cells in the Venus fly trap as hinge cells or midrib cells. Some knew that water enters cells and makes them expand to close the trap.

(b) Most candidates related the decreased surface area of the folded leaf to less absorption of light by chloroplast pigments. A few considered the reduction in carbon dioxide entry to the leaf due to stomata being less exposed to air in the fold. Candidates should consider whether after a change there is less or none of a process happening, as jumping to the conclusion that a process reduces to zero was frequent error.

(c) Most candidates gave at least two similarities between the two forms of photophosphorylation. The most common of these were that both produce ATP and that they do this by chemiosmosis. Candidates generally recalled several differences between the two forms of photophosphorylation but needed to always state clearly that a process occurring in non-cyclic photophosphorylation did

not occur in cyclic. Omissions in descriptions in weaker answers included not mentioning chlorophyll in the context of photoactivation and not describing electron movement in the context of the electron transport chain. Errors included referring to ATP synthase as 'ATPase' and stating that 'energy is produced'. Some candidates also confused reduced NADP in the chloroplast with reduced NAD and FAD in the mitochondrion and wrongly included oxidative phosphorylation in their answer.

Question 5

(a) Many candidates found it challenging to explain what is meant by haploid. The most common correct descriptions were that haploid cells contain a single set of chromosomes and that haploid is represented by the letter 'n' which is half the diploid number.

(b) The liverwort life cycle presented an unfamiliar context for candidates. Some did not notice the instruction that each letter may be used once, more than once or not at all, and gave a single letter on each line whereas a fully correct answer had multiple letters on two of the lines. Candidates quite often related **B** or **D** to sexual reproduction, and most often gave **C** as a stage produced by mitosis. A few identified structure **D** as the site of meiosis.

(c) There were many good answers to explain why reduction division occurs in horses. The most common correct points were that meiosis at the gamete-forming stage avoids doubling of the chromosome number each generation. Some explained that extra sets of chromosomes cause problems and some stated that meiosis leads to genetic variation in either the gametes or the offspring, though some answers needed to specify what this genetic variation applied to. Some candidates described reduction division without explicitly stating the idea of the chromosome number being maintained.

Question 6

(a) (i) The location and method of production of urea was not well known. While many specified the liver as the site, some wrote kidney. Some wrote deamination but related this to just proteins instead of amino acids, or gave the term alone. The weakest answers confused urea the molecule with urine, the product of the nephron that is expelled via the bladder.

(ii) Most candidates understood the osmoregulatory roles of the hypothalamus, posterior pituitary gland and collecting ducts. Some candidates needed to assign the terms 'effector' and 'target cells' to the correct structures (i.e. these terms were omitted). Some candidates stated incorrectly that ADH was the effector. Strong answers repeated the terms receptors, effectors and target cells in order to name a structure associated with each element of the homeostatic control mechanism. While the ultimate effectors are the collecting ducts of the nephron, the involvement of two mechanisms of coordination, nervous system and endocrine system, meant that the posterior pituitary gland was accepted as an effector (of nervous system coordination) as well as relevant parts of the nephron (endocrine coordination). An error sometimes seen was candidates suggesting that the brain contains more than one posterior pituitary gland. A few answers gave the location of the hypothalamus as being in the kidney.

(b) Candidates struggled to convey the main points of the role of the glomerulus and Bowman's capsule in the formation of urine effectively. The most common correct point made was naming the process as ultrafiltration. Descriptions of high pressure in the glomerulus often lacked the detail 'blood pressure' or 'hydrostatic pressure' or were contradicted by a description of molecules moving out of the glomerular capillaries due to diffusion or osmosis. What moves out of the glomerulus was frequently misidentified as blood or plasma. Errors in naming the layers through which water and solute molecules move to enter the capsule were stating that there are gaps in the endothelial cells rather than between them, naming the cells lining the glomerular capillary 'epithelial cells' rather than 'endothelial cells', naming the basement membrane the basal membrane and referring to gaps in the podocyte cells themselves rather than to slit pores between their projections. Those who attempted to describe the significance of a wider afferent arteriole than efferent sometimes just referred to 'a different diameter' rather than specifying which is wider and sometimes referred to the creation of a high pressure in the arteriole rather than in the glomerular capillaries. The words 'filter' and filtrate' were sometimes confused.

(c) The question clearly asked the candidates to suggest what the different values of U:P show. Strong answers related a high U:P to being able to tolerate water shortage by reabsorbing water in the kidneys in order to concentrate the urine, or to being able to conserve water by producing a small volume of concentrated urine. Weaker answers needed to mention the terms ratio, U:P, or 'solute concentration of urine compared to plasma'.

Question 7

(a) (i) Most candidates identified the description of natural selection as disruptive selection. Some answers mentioned competition and selection pressure without specifying 'high competition' and that the selection pressure was limited food availability. A high proportion of answers described the extremes having a selective advantage and the intermediates being selected against. A few candidates described the intermediates being outcompeted for the two types of food.

(ii) Most candidates identified the description of natural selection as stabilising selection. Some answers mentioned competition without specifying 'low competition'. A high proportion stated that intermediates could eat all types of food in this pond. A relatively large number of answers described the extremes being selected against and the intermediates having a selective advantage, although some only gave a partial description that needed to cover all three types of tadpole.

(iii) The majority of candidates correctly sketched a normal distribution curve to show continuous variation of intestine length within the tadpole population of **pond 2**.

(iv) Most candidates scored some credit here. A high proportion of answers conveyed the idea that sympatric speciation occurs without a geographical barrier, and many mentioned behavioural isolation. While many answers mentioned reproductive isolation developing, relatively few linked this to the formation of new species.

(b) Most answers referenced DNA sequences in the context of determining evolutionary relationships. Many candidates also expressed the idea of analysing base similarities, using a wide range of different wordings. A proportion of answers explained that more similarities in DNA sequences meant a closer relationship, with quite a few mentioning that these analyses can be conducted using bioinformatics or by using a database. Few realised that *S. hammondii* and *S. bombifrons* have the fewest genetic differences with many just stating that they have the closest evolutionary relationship.

Question 8

(a) Strong answers described the reverse transcriptase method of synthesising a gene from an mRNA template and some also showed knowledge of artificial chemical synthesis by joining component nucleotides in the correct order, using a known sequence of letters obtained from a database. There were many weaker candidates who did not answer the question and linked the context of genetic engineering to CRISPR and inserting DNA into plasmids instead.

(b) Most candidates linked DNA ligase to adding a gene to a plasmid, and DNA polymerase to adding nucleotides to a polynucleotide. Stronger candidates knew that ligase joins two sections of sugar phosphate backbone. Many thought that DNA polymerase does this too, but adding a new single nucleotide that consists of a sugar, a base and a phosphate is not adding a 'section' that is described as having a 'sugar phosphate backbone' because it consists of several nucleotides. This was a question where most candidates gained the majority or all of the credit available. There were some responses where squares were left blank.

(c) Weaker answers gave no temperatures for this question. Occasionally figures were given for temperatures that lacked the unit degrees Celsius. An error in describing the DNA denaturation step was to omit the term DNA or to state that enzymes denature. Errors in describing the annealing step were to write 'probe' or 'promoter' instead of 'primer'. For the elongation phase some answers omitted the name of the enzyme, or wrote that *Taq* or DNA polymerase 'transcribes' a new strand of DNA instead of synthesises or replicates it.

Question 9

(a) Candidates varied in their knowledge of the characteristic features of the kingdoms Protoctista and Fungi. More facts were known about Fungi, for example that they reproduce by spores, have a cell wall of chitin, are heterotrophic and have hyphae. Some candidates also knew that both kingdoms are eukaryotic, although weaker answers described prokaryotic features for Protoctista. Few candidates described the variation seen in Protoctista such as the range of autotrophic and heterotrophic species, or some with cell walls of cellulose and some with no cell walls. For full credit, a balanced answer was required that covered both kingdoms.

(b) (i) Some candidates realised that the significance of quantifying lichen distributions is to gain information about air pollution. A few took this idea further with a consideration of whether other species in the ecosystem might be affected by sulfur dioxide pollution, or whether other species depend on lichens for food. Some answers did suggest that the information might lead to introducing conservation measures to control air pollution.

(ii) Answers included a range of ideas ranging from moral and aesthetic reasons to conserve lichens, to utilitarian considerations, such as potential use in medicine or as a future source of genes. There are in fact a range of chemicals in lichens with medical applications, including antimicrobial and anti-inflammatory chemicals. Many answers also considered the roles of lichens in supporting other species.

Question 10

(a) Most candidates showed a monohybrid cross between two heterozygotes and summarised with a 3:1 ratio of melanic to typical moths. Some candidates confused the dominant and recessive alleles, some chose incorrect parents and some made the gametes diploid and the moths tetraploid. The most common errors were omissions. Some omitted to show the parental genotypes and some left out the final ratio of offspring phenotypes.

(b) Most identified that the allele in both cases was dominant. Incorrect answers included epistasis, sex linkage and heterozygous.

(c) (i) Some candidates knew that a test cross involved one homozygous recessive partner but needed to relate this knowledge to the question context. Strong answers identified the typical offspring from cross 1 as being the homozygous recessive partner or alternatively referred to crossing the melanic offspring of cross 1 with a homozygous recessive.

(ii) This was a challenging question, even for the stronger candidates. Some worked out that the genotypes of melanic moths from cross 2 if the two alleles were at the same locus would be AA and Aa. The commonest error was to add 'aa' but the genotypes needed to correspond to melanic moths as stated in the left-hand column of the table. The most common error when considering if the genotypes in the two alleles were at different loci was to show genotypes that were homozygous for one of the dominant alleles, or to give haploid genotypes like 'AB' instead of 'AaBb'. Some candidates worked out 1 in 3 for the proportion of test crosses giving all melanic offspring where alleles were at the same locus, and very few realised that if the alleles occurred at separate loci, then no crosses would give all melanic offspring.

(d) This question was very well done with the vast majority of candidates completing the Lincoln index calculation successfully to give the population size as 87.

BIOLOGY

Paper 9700/42
A Level Structured Questions 42

Key messages

- Candidates should remember that using precise words in answers is very important. For example, in **Question 6(b)(i)**, the terms volume, mass or concentration should be used rather than amount or quantity.
- Figures quoted from a graph must be as accurate as possible. Many candidates were not accurate enough in **Question 3(c)(i)** and **Question 9(b)**.
- Candidates should note that if abbreviations are used, they should be those that are given in the syllabus, such as RuBP and GP. If a candidate wishes to use an abbreviation not in the syllabus, this is acceptable provided it is explained the first time it is used, for example: distal convoluted tubule (DCT).

General comments

Questions 3, 5 and **10** proved to be quite challenging. In **Question 3(c)(i)**, the importance of carefully reading all of the information given in the question was apparent as many misunderstood the information provided in the graph.

For **Question 5(b)**, candidates could improve their approach by first looking at the data and calculating the mean, then:

- looking at the spread of the results around that mean, **b(i)** the standard deviation
- using that in a statistical test, **b(ii)** complete the *t*-test
- making a conclusion from the data and deciding if the difference in the means is or is not significant, **b(iii)**. In this case, the *t*-test value > critical value, so there is a significant difference between means so the difference is not due to chance
- suggesting possible causes of this difference, **b(iv)** – genetic/environmental.

Comments on specific questions

Question 1

(a) (i) Most candidates were able to name structure **A** as a podocyte and structure **B** as either the endothelium or an endothelial cell. Common incorrect answers for **B** were epithelium/epithelial cell and basement membrane.

(ii) Many candidates understood that high hydrostatic, or blood, pressure would be one condition required for ultrafiltration, although some simply mentioned a pressure gradient between the glomerulus and Bowman's capsule without further clarification. Some candidates suggested differences in water potential or solute concentration were necessary, neither of which gained any credit. A few commented that the basement membrane would act as a filter, or alternatively, stated the size of molecules which would or would not pass across it.

(b) Identifying the changes, if any, between the blood plasma in the glomerulus and the newly formed glomerular filtrate proved to problematic and few candidates scored full credit. Most understood that large proteins would be absent in the glomerular filtrate as well as the urine. Many responses suggested that there would be more urea and glucose in the filtrate rather than these remaining the same. Those who recognised that the concentrations would not change between the plasma and

the filtrate often then went on to state correctly that glucose would no longer be present in the urine, while the concentration of urea would increase.

(c) The responses of the kidney and posterior pituitary gland to sweating were generally well understood. Most appreciated that sweating would initiate mechanisms to conserve water, firstly by the posterior pituitary gland increasing the release of ADH. Many then stated that the kidney would reabsorb more water from the collecting duct, or that more aquaporins would be added to the collecting duct membrane, increasing its permeability to water. References to the production of a smaller volume of concentrated urine were less common. Some candidates needed to mention the collecting duct membrane, or simply comment that water would be reabsorbed, rather than increase.

Question 2

(a) Many candidates scored very well on this question, identifying and showing a good understanding of a range of processes affecting allele frequencies. Most gained credit for referring to genetic drift, founder effect and bottleneck effect. The majority gave natural selection as a reason. Sometimes responses consisted of a detailed description of natural selection which was not credited. This question required candidates to outline the processes. Mutation was also a common answer and some mistakenly stated that mutations were caused by environmental change rather than that they occurred spontaneously.

Some misinterpreted the question and explained the processes of speciation while others wrote about artificial selection, selective breeding, hunting and habitat destruction, rather than processes in wildlife populations, which were not relevant.

Few candidates identified the process of migration or gene flow allowing for allele frequencies to change due to the introduction or removal of individuals (and their alleles) from the population. The idea of linkage groups being broken during crossing over causing genetic recombination and a possible change in allele frequency, was rarely seen. As genes are no longer linked together it means that alleles are no longer inherited together.

Many candidates recognised that a small population was significant for genetic drift and many, instead of highlighting that the effect of genetic drift is larger in small populations, mistakenly wrote that genetic drift only occurs in small populations. A frequent error was the conflation of genetic drift with gene flow or not recognising how events like bottlenecks or founder effects can lead to significant shifts in allele frequencies due to small population sizes.

(b) This question found to be challenging by a large proportion of candidates. An outline was required of inbreeding and hybridisation to produce vigorous, uniform varieties of maize. Firstly, uniform plants are obtained by inbreeding plants for the desired height over many generations to increase homozygosity. Because these plants will be susceptible to inbreeding depression, the next step is for hybridisation to introduce hybrid vigour (vigorous plants). This is done by outbreeding by selecting two different inbred (homozygous) varieties and crossbreeding them.

Most responses showed a general understanding of the process of selective breeding, often achieving credit for a description of inbreeding.

A common mistake was not explaining how inbreeding repeatedly amplifies desirable traits (in this case uniform height) by increasing the frequency of specific alleles over multiple generations. Instead, responses often just focused on the repeating for many generations statement.

More thorough answers included reference to outbreeding, and many went on to explain the reason for this in terms of gaining hybrid vigour. References to homozygosity and heterozygosity were quite rare. A common misconception was that a vigorous plant was a trait that was selected for instead of the idea of heterozygosity due to hybridisation to obtain vigour. A small number of candidates confused selective breeding with genetic engineering and wrote about choosing alleles. Some candidates also confused selective breeding with natural selection, leading to imprecise answers.

Question 3

(a) This question required candidates to explain that genetic engineering is the deliberate manipulation of genetic material to modify specific characteristics of an organism and that this may involve transferring a gene into an organism so that the gene is expressed.

Those who had good syllabus knowledge easily gained full credit. They were able to explain that genetic material was manipulated. Many made good use of the terms 'recombinant DNA' or 'recombinant plasmids' to explain how the manipulation occurred and knew that the result produced GMOs. Stronger candidates also knew that a gene was transferred into a new organism and it was then expressed to give a protein and thus modify a specific characteristic. Some gave the production of insulin as a good example of this scenario. A small number of candidates with good syllabus knowledge referred to gene editing, which the syllabus describes as a form of genetic engineering.

Weaker candidates often gave long answers about changing DNA or genes and adding them to plasmids using ligases or making DNA and genes using the PCR, while others needed to be more specific that a gene was transferred into an organism and refer to the transfer of DNA. Candidates should avoid imprecise statements such as genetic make-up or information and be more specific with genetic material or named examples of DNA or genes.

(b) (i) This proved to be a challenging area of the syllabus and many candidates were unable to outline how this disease could be treated with gene therapy.

Some responses showed an excellent understanding of the process. They outlined the first step as adding the functional allele to the virus which is then injected into the eye. The strongest responses explained that the gene would be incorporated in the eye cell DNA and that expression of the gene would lead to the production of the functional protein, thus keeping the cells in the retina alive and restoring eyesight. A few candidates excelled as they knew the specific virus used as a vector – the adeno-associated virus (AAV).

While some understood that a vector was necessary, they frequently incorrectly suggested that a plasmid was involved, which could receive the functional gene and then be directly inserted into the eye, or that the modified plasmid could be inserted into the virus before being inserted into the eye. The possibility that genes could just be 'removed' and then 'replaced' by injecting new functional genes directly into the eye without an intermediary was an incorrect answer frequently seen in various forms.

(ii) Many candidates understood that the eye is a suitable organ for gene therapy due to the low risk of an immune response or that it is easily accessible as the site of the injection. A significant few referred to its small size and missed out on credit as they needed to go on to relate this to the small amount of gene therapy treatment that would be needed. Some candidates incorrectly suggested it was because we had two eyes so it was acceptable to lose one, and several candidates chose to respond by stating the eye was suitable because that is where the problem was or where the faulty gene was located.

(c) (i) The key to this question came right at the end of the information page with the statement 'A negative change in the visual acuity score shows an improvement in visual acuity.' It was very clear from the answers given, that the majority of candidates did not understand this information and gave detailed descriptions of the ups and downs of the two data lines. There were many contradictory responses; candidates were aware that treatment must be to try to improve visual acuity and yet the trend of the line went downwards, which often created conflict in answers. Candidates frequently referred to the 'change' in visual acuity rather than the improvement. There was some confusion by candidates not recognising that a more negative value was an improved visual acuity, and instead incorrectly stating it was a decrease in visual acuity. When they referred to the overall improvement in acuity they often did so while comparing the treated and untreated eye and so gained credit.

A large minority were not accurate when taking readings from the graph. Many candidates did an almost month by month account of the change in visual acuity rather than a simpler description of the overall improvement in visual acuity.

(ii) Generally, this question was found to be challenging. Stronger candidates understood the process very well and could explain how the removal of the mutated DNA resulted in the functional protein being made. A small number of these mentioned the fact that it acts on the person's own DNA. Most candidates were very focused on the editing and needed to link the mutation in the DNA to the defective protein so that any corrective therapy would lead to a functional protein. Many candidates did not score any credit on this question, often referring to entire genes or exon X being removed rather than the mutated DNA. Many repeated the information provided in the question and only some provided their own interpretation of this information – which was usually in regard to the specific part of DNA that was removed.

Question 4

(a) This question was well answered by the majority of candidates. Those who correctly identified the genotypes of the parents as both being **Rr** were usually able to gain full credit. The most common mistake was not to link the phenotype (red or yellow) to the genotype of the offspring.

Candidates who did not start with the correct genotypes mistakenly described the cross between the original pure breeding parents, suggesting a simple misunderstanding of the meaning of F1 and F2 generations.

A minority of candidates needed to use the symbols suggested and credit was given if they used upper and lower case of the same letter, such as **Aa**.

(b) Stronger candidates correctly stated the ratio of 9:3:3:1 and went on to state that independent assortment occurred in metaphase I.

A variety of incorrect ratios were given, with some candidates giving simple monohybrid ratios. From an incorrect ratio it was very rare to score for the explanation, although a few gained credit for referring to independent assortment. Common errors were references to crossing over and random fertilisation and explanations involving dominant and recessive alleles, and occasionally epistasis.

Question 5

(a) All but the weakest candidates answered this question well. There did not appear to be a trend in the incorrect responses although the third statement about the additive effect of genes provided the most doubt.

(b) (i) Many candidates were unsure what standard deviation is and provided a range of incorrect suggestions. Those who had a reasonable idea of the meaning sometimes needed to suggest that it is the spread of a single value around the mean, rather than the whole data set. Some responses gave confused explanations of the calculation, for instance, the square root of variance. A large number mentioned the spread of data without mentioning the mean, so did not gain the credit.

(ii) This was very well answered with many candidates correctly calculating the value of *t*. Weaker candidates were unable to substitute the data into the equation correctly or made calculation errors. Some candidates needed to answer to four significant figures as directed in the question. Candidates who struggled with this calculation usually obtained credit for providing the correct numerator value. It was important to show all working with unrounded answers for each step of the calculation so that even if their final answer was incorrect, working marks could be awarded. Many candidates did not do this. A common error was to forget to square each standard deviation in the denominator and arrive at 12.02 instead of the correct figure of 4.255 as the final answer.

(iii) A small number of candidates achieved full credit on this question; to do so, most needed to refer to **Table 5.2** and state a conclusion as directed that there was a higher mean concentration of serum 25-OHD in summer. Of the small number of candidates who wrote a conclusion, some mentioned 'level' rather than 'concentration,' so did not gain credit.

It was not unusual for candidates to misunderstand the point of the *t*-test and suggest that there is or is not a correlation shown in the data. Most compared the value of *t* to the critical value but they did not always understand that the value of *t* being greater than the critical value means that there is a significant difference between the two means, and those who stated that this was the case, often stopped short of explaining that the significant difference is between the two means. Most

candidates focused on rejecting the null hypothesis and needed to go on to then restate the hypothesis that there is a significant difference between the two means. When commenting on whether the difference is due to chance, numerous candidates needed to refer to the probability level as a percentage.

(iv) The question asked for the likely causes of this continuous variation, the plural indicating that there would be both genetic and environmental causes. A very few responses included both a genetic cause and an environmental cause to score the credit here. Answers usually referred to an environmental factor alone, such as time in the sun or diet.

Question 6

(a) (i) The strongest candidates gave the correct answer of redox as the category of indicators.

(ii) The correct answer of blue to colourless was often given. Common errors were to not give a change, or to state white instead of colourless.

(b) (i) Generally, a well-answered question with most candidates being awarded full credit here for the same concentration or volume of the glucose solution, yeast suspension or DCPIP. Candidates should remember that the word 'amount' is not acceptable.

A frequent incorrect term was temperature, as the experiment was based on varying temperature.

(ii) This question was well attempted by most candidates. Some linked the colour change to the temperature instead of the rate of respiration of the yeast. These responses could go on to gain full credit for stating that the decrease in time for DCPIP to change colour was due to an increase in kinetic energy and more enzyme-substrate complexes being formed. Many mentioned that the optimum temperature was 40 °C and that the enzyme would be denatured above 40 °C.

Some candidates needed to read the question more carefully as they only described the results rather than giving any explanation.

Question 7

(a) This question was well answered by many candidates who stated that the R_f value of the pigment would be calculated by dividing the distance moved by the pigment by the distance moved by the solvent. Strong candidates then went on to state that the R_f value would need to be compared to a reference table to identify the pigments.

Some needed to read the question more carefully as they spent time describing how pigments are separated by chromatography instead of following the instruction to describe how the results can be used.

(b) Many candidates correctly identified carotene and xanthophyll as accessory pigments. Some were able to state that these pigments absorbed different wavelengths of light, and could have gone on to state, for further credit, that the wavelengths were those not absorbed by the reaction centre, primary pigments or chlorophyll *a*. Many were able to explain that the light energy was passed on to the reaction centre, primary pigments or chlorophyll *a*; some omitted to include the word energy.

(c) Most candidates displayed a good knowledge of the light-independent stage of photosynthesis and named it the Calvin cycle. Good answers referred to carbon fixation being carried out by rubisco in combining carbon dioxide to RuBP to produce an unstable 6-carbon compound that splits into two molecules of GP. Common errors at this point were to not mention that the 6-carbon compound was unstable or that two molecules of GP were formed. Many were able to show that GP was converted to TP and needed to mention that this was a reduction reaction. The use of TP in generating other organic compounds or regenerating RuBP was given by many.

Those candidates who misread the question and gave detailed accounts of the light-dependent stage were unable to score any credit.

Question 8

(a) (i) The vast majority of candidates were able to name part **Y** of a motor neurone as the cell body, cytoplasm or soma. Stronger candidates identified cell **X** as a Schwann cell, rather than the myelin sheath given by some who had not fully noted the detail of the question.

(ii) This section was found to be challenging often because candidates had not noticed that structure **Z** extended from the cell body and so would only synapse with either a sensory or relay neurone in the spinal cord. Many mistakenly assumed that the question was asking them to state what the motor end plate would synapse with and therefore gave their answer as muscle cell.

(b) Many candidates were able to list the correct sequence of events occurring during muscle contraction. Common errors were to confuse depolarisation of the T-tubules with depolarisation of the sarcolemma, and giving myosin heads tilting before they had bound to actin. Many gained credit for having the correct letters in each section (1 to 5 or 6 to 10), even if they were not in the correct order. Weaker candidates were unable to score any credit.

(c) Stronger candidates were able both to suggest and explain why LEMS leads to weaker muscle contraction, beginning their account by stating that binding of the antibodies to the calcium ion channels would prevent the entry of calcium ions into the presynaptic knob, which in turn would prevent vesicles containing acetylcholine from moving towards and fusing with the presynaptic membrane. Weaker candidates suggested that calcium ions would not be released by the channels or would be unable to enter the membrane rather than the presynaptic knob. However, most appreciated that acetylcholine would not be released by exocytosis and therefore could not bind to receptors on the sarcolemma, although they did not gain credit for stating that the receptors were on the postsynaptic knob. Many went on to add that sodium ion channels would not open, preventing depolarisation of the sarcolemma and the generation of an action potential. Weaker candidates referred to voltage-gated, rather than ligand-gated sodium channels, or missed out the name of the membrane which would not be depolarised. Many candidates gained credit for suggesting a process inside the muscle fibre which could no longer take place, most commonly for calcium ions not being released from the sarcoplasmic reticulum or not binding to troponin.

Question 9

(a) Most candidates were able to suggest many reasons why the red ruffed lemur has become critically endangered, the most frequent being habitat destruction, hunting, poaching or increased predation, and climate change. Some appreciated that food or other resources might become scarce and could have mentioned competition, while others stated that disease may affect the population without any further qualification. References to the illegal trade in fur or pets were rare.

(b) In general, candidates described the changes in the number of captive-born red ruffed lemurs in **Fig. 9.2** very well. Most appreciated that the most rapid increase in number occurred between 1980 and 1990, after which the numbers became constant with only slight fluctuations between 2000 and 2020. There was occasional misquoting of figures from the graph, particularly for 1980, but most candidates were able to gain credit for giving correct figures for other years. Weaker candidates needed to offer any figures from the graph or simply state that the number of captive-born lemurs increased then levelled off.

(c) (i) The problems affecting the success of the lemurs' captive breeding programme were well understood by the majority of candidates. Many suggested that the lemurs might refuse to breed as a result of the stress of being kept in an unnatural environment. Others were aware that there may not be enough suitable mates available for breeding. Some commented on the fact that any captive breeding programme is expensive to conduct and that inbreeding depression might result due to the limited number of animals. Fewer mentioned the possibility of infertility or disruption of the reproductive cycle. Weaker candidates believed that captive breeding programmes would affect the survival of the lemurs in the wild or that the zoos would not be sufficiently well-equipped or knowledgeable to run them.

(ii) Most candidates appreciated that the introduction of wild-caught lemurs into the captive breeding programme would be to increase genetic variation, expressed in a variety of ways, such as increasing the gene pool, increasing heterozygosity, or reducing inbreeding depression. Weaker candidates suggested that it was for the protection of the endangered species, preventing their extinction and ensuring their survival in the wild.

Question 10

(a) While the majority of candidates were familiar with the concept of homeostasis, often beginning their response with a definition, explanations of the principles involved were often poorly expressed. Weaker candidates simply provided an overview of how factors such as blood glucose concentration or temperature would be controlled without details of the precise mechanisms. Stronger candidates understood that a change in a parameter would be detected by a receptor and that impulses would be sent to the brain or central nervous system. Impulses or hormones would then be transmitted to an effector to carry out the appropriate response. Credit was most frequently awarded for understanding that negative feedback would return any change in a parameter to the set point or norm. Some illustrated their answers with suitable examples, such as the role of the liver in regulating blood glucose concentration upon stimulation by either insulin or glucagon. Credit was often lost when candidates needed to use the appropriate biological terms, such as signals and messages instead of impulses or hormones.

(b) Candidates frequently found it difficult to suggest and explain why cell signalling by glucagon is likely to be affected in the liver cells of a person with GSDV1. Stronger candidates recognised that normal cell signalling by glucagon would still take place, giving comprehensive accounts of the mechanisms which would be triggered following the binding of glucagon to its receptor, while weaker ones stated that the whole signalling cascade would not take place at all. Few candidates went on to add that glycogen phosphorylase would not be produced, activated or able to function, although they understood that there would be no conversion of glycogen to glucose. Stronger candidates who appreciated that glycogen phosphorylase would be non-functional often suggested that this could be due to changes in the tertiary structure of the enzyme, resulting in a change in the shape of the active site.

(c) Most candidates were able to suggest that one of the consequences of a person with GSD0 having a meal rich in glucose would be a high, or increased, blood glucose concentration, although some missed out by writing about glucose 'levels' instead of concentration. Although relatively few linked this to the appearance of glucose in the urine, many commented on the symptoms which might be seen, such as thirst, fatigue or ultimately coma, or the effect on blood water potential or blood pressure. Very few attributed these consequences to the lack of synthesis or activation of glycogen synthase. References to either increased lipid synthesis or inhibition of glucagon secretion were rare.

BIOLOGY

Paper 9700/43
A Level Structured Questions 43

Key messages

The majority of candidates wrote clearly and presented creditable work. In a significant number of scripts, handwriting needed to be improved to ensure that responses could be deciphered and awarded all of the credit due.

There were a few whose answers regularly overflowed the answer space and continued down the side margins of the page. Candidates should plan their answer so that they make the same number of points as there are marks available, in a way that uses the amount of answer space provided.

General comments

Many candidates were well prepared and showed a thorough knowledge of the syllabus topics and well-trained skills in the analysis of data and interpretation of new contexts. The most successful answers were those that showed attention to detail and that were expressed clearly and logically. The most common areas for improvement that could have led to additional credit were reading the question more carefully and making sure to follow the question rubric. The areas of Biology where candidates showed most knowledge and understanding were nervous transmission (**Question 1**), stomatal opening (**Question 2**), respiration (**Question 3**) and using the Lincoln index (**Question 10(d)**). Questions involving inheritance and molecular genetics were found to be more challenging (**Questions 5, 7, 8** and **10(c)**). Correct and precise use of terminology is essential when thinking and writing about genetics and applications of knowledge of DNA.

Comments on specific questions

Question 1

(a) (i) Many candidates named two structures correctly, usually dendrites (**A**) and nuclei (**B**). For **C**, the label line pointed to the swollen end adjacent to the synapse and the specific term 'synaptic knob' was required, not the less specific 'axon terminal'. It should be noted that the synaptic knob is always before the synaptic cleft, i.e. presynaptic, and it is unnecessary and a mistake to name it as 'presynaptic knob'.

(ii) Most candidates answered this question correctly. Answers mostly identified the rat as having a myelinated axon or Schwann cells and made reference to or described saltatory conduction. Some candidates needed to specify which animal's neurone they were discussing; as the question referred to both, this needed to be made clear.

(b) The most successful candidates made use of the correct terms for describing parts of the action potential, e.g. depolarisation, repolarisation, the refractory period and hyperpolarisation. They made comparative points, read figures to within half a grid square from the graphs and specified which animal's neurone took longer for a certain stage to be completed or which animal's neurone reached a greater depolarisation at the peak of the action potential. Common errors were pointing out similarities although the question asked candidates to contrast and quoting figures without specifying exactly what these referred to by using the appropriate term. Weaker responses sometimes misused the term threshold potential when they meant the peak of depolarisation of the action potential.

Question 2

(a) Many candidates gave clear answers, specifying when stomata open and close over a 24-hour period and why. Weaker candidates needed to use the 24-hour period as a frame of reference for their discussion of what stomata do and why, although many stated that open stomata allowed carbon dioxide to enter for photosynthesis and that they closed to prevent water loss by transpiration.

(b) Overall, candidates performed very well on this question. Most noted the reference to guard cells in the question and framed their answer correctly in terms of movements of ions and water in and out of these cells, and not in and out of the pores themselves (stomata). Candidates generally showed detailed knowledge of the mechanism of stomatal opening. Few stated that the pumping of protons out of the guard cell results in the charge inside the cell membrane becoming more negative than before (as opposed to just negative, which is always the case). It was also rare for candidates to describe the thicker inner cell walls of a pair of guard cells and the thinner outer walls causing the cell to bend so that the stoma opened. A few candidates described the graph instead.

(c) This was a challenging question where candidates who had some understanding of the right idea found it hard to put these into words. The evidence for genetic control was the continuation of the 24-hour repeating pattern of opening and closing when the plant was kept in the dark. The evidence for a role for the environment was the peak number of open stomata decreasing over successive cycles in the absence of a daily light stimulus. The strongest candidates made both of these points.

Question 3

(a) Candidates were best at identifying covalent bond formation between coenzyme A and an acetyl group in the link reaction and in selecting the link reaction and Krebs' cycle as the stages that release carbon dioxide. The most common error in identifying which events occurred at different stages of aerobic respiration was thinking that catabolism happens in oxidative phosphorylation. Where candidates are asked to put ticks and crosses in a table, they must follow the rubric and not leave squares blank.

(b) (i) The majority of answers showed how RQ is calculated and gave the figures for carbohydrates and lipids. Most of these needed to go on to use the information from the question to explain that the air flow meter would measure the oxygen intake, and the carbon dioxide sensor would determine the concentration of carbon dioxide exhaled.

(ii) The majority selected lipids as having the higher energy value. Candidates frequently made reference to lipids having more hydrogen atoms or more carbon-hydrogen bonds and some went on to relate this to more reduced NAD forming, leading to a greater proton gradient. Common mistakes were to confuse energy value with RQ, to quote figures for energy content with the wrong unit (just kJ or kJ mol^{-1} instead of the correct kJ g^{-1}) and to write about lipids having more hydrogen molecules or more hydrogen bonds.

Question 4

(a) Candidates' recall of events that lead to shutting of the lobes of the Venus fly trap was an area in need of improvement. The most remembered point was the need for two sensory hairs to be touched, as opposed to the single touch trigger for the folding of the leaf in *Mimosa pudica*. Few candidates named the relevant cells in the Venus fly trap as hinge cells or midrib cells. Some knew that water enters cells and makes them expand to close the trap.

(b) Most candidates related the decreased surface area of the folded leaf to less absorption of light by chloroplast pigments. A few considered the reduction in carbon dioxide entry to the leaf due to stomata being less exposed to air in the fold. Candidates should consider whether after a change there is less or none of a process happening, as jumping to the conclusion that a process reduces to zero was frequent error.

(c) Most candidates gave at least two similarities between the two forms of photophosphorylation. The most common of these were that both produce ATP and that they do this by chemiosmosis. Candidates generally recalled several differences between the two forms of photophosphorylation but needed to always state clearly that a process occurring in non-cyclic photophosphorylation did

not occur in cyclic. Omissions in descriptions in weaker answers included not mentioning chlorophyll in the context of photoactivation and not describing electron movement in the context of the electron transport chain. Errors included referring to ATP synthase as 'ATPase' and stating that 'energy is produced'. Some candidates also confused reduced NADP in the chloroplast with reduced NAD and FAD in the mitochondrion and wrongly included oxidative phosphorylation in their answer.

Question 5

(a) Many candidates found it challenging to explain what is meant by haploid. The most common correct descriptions were that haploid cells contain a single set of chromosomes and that haploid is represented by the letter 'n' which is half the diploid number.

(b) The liverwort life cycle presented an unfamiliar context for candidates. Some did not notice the instruction that each letter may be used once, more than once or not at all, and gave a single letter on each line whereas a fully correct answer had multiple letters on two of the lines. Candidates quite often related **B** or **D** to sexual reproduction, and most often gave **C** as a stage produced by mitosis. A few identified structure **D** as the site of meiosis.

(c) There were many good answers to explain why reduction division occurs in horses. The most common correct points were that meiosis at the gamete-forming stage avoids doubling of the chromosome number each generation. Some explained that extra sets of chromosomes cause problems and some stated that meiosis leads to genetic variation in either the gametes or the offspring, though some answers needed to specify what this genetic variation applied to. Some candidates described reduction division without explicitly stating the idea of the chromosome number being maintained.

Question 6

(a) (i) The location and method of production of urea was not well known. While many specified the liver as the site, some wrote kidney. Some wrote deamination but related this to just proteins instead of amino acids, or gave the term alone. The weakest answers confused urea the molecule with urine, the product of the nephron that is expelled via the bladder.

(ii) Most candidates understood the osmoregulatory roles of the hypothalamus, posterior pituitary gland and collecting ducts. Some candidates needed to assign the terms 'effector' and 'target cells' to the correct structures (i.e. these terms were omitted). Some candidates stated incorrectly that ADH was the effector. Strong answers repeated the terms receptors, effectors and target cells in order to name a structure associated with each element of the homeostatic control mechanism. While the ultimate effectors are the collecting ducts of the nephron, the involvement of two mechanisms of coordination, nervous system and endocrine system, meant that the posterior pituitary gland was accepted as an effector (of nervous system coordination) as well as relevant parts of the nephron (endocrine coordination). An error sometimes seen was candidates suggesting that the brain contains more than one posterior pituitary gland. A few answers gave the location of the hypothalamus as being in the kidney.

(b) Candidates struggled to convey the main points of the role of the glomerulus and Bowman's capsule in the formation of urine effectively. The most common correct point made was naming the process as ultrafiltration. Descriptions of high pressure in the glomerulus often lacked the detail 'blood pressure' or 'hydrostatic pressure' or were contradicted by a description of molecules moving out of the glomerular capillaries due to diffusion or osmosis. What moves out of the glomerulus was frequently misidentified as blood or plasma. Errors in naming the layers through which water and solute molecules move to enter the capsule were stating that there are gaps in the endothelial cells rather than between them, naming the cells lining the glomerular capillary 'epithelial cells' rather than 'endothelial cells', naming the basement membrane the basal membrane and referring to gaps in the podocyte cells themselves rather than to slit pores between their projections. Those who attempted to describe the significance of a wider afferent arteriole than efferent sometimes just referred to 'a different diameter' rather than specifying which is wider and sometimes referred to the creation of a high pressure in the arteriole rather than in the glomerular capillaries. The words 'filter' and filtrate' were sometimes confused.

(c) The question clearly asked the candidates to suggest what the different values of U:P show. Strong answers related a high U:P to being able to tolerate water shortage by reabsorbing water in the kidneys in order to concentrate the urine, or to being able to conserve water by producing a small volume of concentrated urine. Weaker answers needed to mention the terms ratio, U:P, or 'solute concentration of urine compared to plasma'.

Question 7

(a) (i) Most candidates identified the description of natural selection as disruptive selection. Some answers mentioned competition and selection pressure without specifying 'high competition' and that the selection pressure was limited food availability. A high proportion of answers described the extremes having a selective advantage and the intermediates being selected against. A few candidates described the intermediates being outcompeted for the two types of food.

(ii) Most candidates identified the description of natural selection as stabilising selection. Some answers mentioned competition without specifying 'low competition'. A high proportion stated that intermediates could eat all types of food in this pond. A relatively large number of answers described the extremes being selected against and the intermediates having a selective advantage, although some only gave a partial description that needed to cover all three types of tadpole.

(iii) The majority of candidates correctly sketched a normal distribution curve to show continuous variation of intestine length within the tadpole population of **pond 2**.

(iv) Most candidates scored some credit here. A high proportion of answers conveyed the idea that sympatric speciation occurs without a geographical barrier, and many mentioned behavioural isolation. While many answers mentioned reproductive isolation developing, relatively few linked this to the formation of new species.

(b) Most answers referenced DNA sequences in the context of determining evolutionary relationships. Many candidates also expressed the idea of analysing base similarities, using a wide range of different wordings. A proportion of answers explained that more similarities in DNA sequences meant a closer relationship, with quite a few mentioning that these analyses can be conducted using bioinformatics or by using a database. Few realised that *S. hammondii* and *S. bombifrons* have the fewest genetic differences with many just stating that they have the closest evolutionary relationship.

Question 8

(a) Strong answers described the reverse transcriptase method of synthesising a gene from an mRNA template and some also showed knowledge of artificial chemical synthesis by joining component nucleotides in the correct order, using a known sequence of letters obtained from a database. There were many weaker candidates who did not answer the question and linked the context of genetic engineering to CRISPR and inserting DNA into plasmids instead.

(b) Most candidates linked DNA ligase to adding a gene to a plasmid, and DNA polymerase to adding nucleotides to a polynucleotide. Stronger candidates knew that ligase joins two sections of sugar phosphate backbone. Many thought that DNA polymerase does this too, but adding a new single nucleotide that consists of a sugar, a base and a phosphate is not adding a 'section' that is described as having a 'sugar phosphate backbone' because it consists of several nucleotides. This was a question where most candidates gained the majority or all of the credit available. There were some responses where squares were left blank.

(c) Weaker answers gave no temperatures for this question. Occasionally figures were given for temperatures that lacked the unit degrees Celsius. An error in describing the DNA denaturation step was to omit the term DNA or to state that enzymes denature. Errors in describing the annealing step were to write 'probe' or 'promoter' instead of 'primer'. For the elongation phase some answers omitted the name of the enzyme, or wrote that *Taq* or DNA polymerase 'transcribes' a new strand of DNA instead of synthesises or replicates it.

Question 9

(a) Candidates varied in their knowledge of the characteristic features of the kingdoms Protoctista and Fungi. More facts were known about Fungi, for example that they reproduce by spores, have a cell wall of chitin, are heterotrophic and have hyphae. Some candidates also knew that both kingdoms are eukaryotic, although weaker answers described prokaryotic features for Protoctista. Few candidates described the variation seen in Protoctista such as the range of autotrophic and heterotrophic species, or some with cell walls of cellulose and some with no cell walls. For full credit, a balanced answer was required that covered both kingdoms.

(b) (i) Some candidates realised that the significance of quantifying lichen distributions is to gain information about air pollution. A few took this idea further with a consideration of whether other species in the ecosystem might be affected by sulfur dioxide pollution, or whether other species depend on lichens for food. Some answers did suggest that the information might lead to introducing conservation measures to control air pollution.

(ii) Answers included a range of ideas ranging from moral and aesthetic reasons to conserve lichens, to utilitarian considerations, such as potential use in medicine or as a future source of genes. There are in fact a range of chemicals in lichens with medical applications, including antimicrobial and anti-inflammatory chemicals. Many answers also considered the roles of lichens in supporting other species.

Question 10

(a) Most candidates showed a monohybrid cross between two heterozygotes and summarised with a 3:1 ratio of melanic to typical moths. Some candidates confused the dominant and recessive alleles, some chose incorrect parents and some made the gametes diploid and the moths tetraploid. The most common errors were omissions. Some omitted to show the parental genotypes and some left out the final ratio of offspring phenotypes.

(b) Most identified that the allele in both cases was dominant. Incorrect answers included epistasis, sex linkage and heterozygous.

(c) (i) Some candidates knew that a test cross involved one homozygous recessive partner but needed to relate this knowledge to the question context. Strong answers identified the typical offspring from cross 1 as being the homozygous recessive partner or alternatively referred to crossing the melanic offspring of cross 1 with a homozygous recessive.

(ii) This was a challenging question, even for the stronger candidates. Some worked out that the genotypes of melanic moths from cross 2 if the two alleles were at the same locus would be AA and Aa. The commonest error was to add 'aa' but the genotypes needed to correspond to melanic moths as stated in the left-hand column of the table. The most common error when considering if the genotypes in the two alleles were at different loci was to show genotypes that were homozygous for one of the dominant alleles, or to give haploid genotypes like 'AB' instead of 'AaBb'. Some candidates worked out 1 in 3 for the proportion of test crosses giving all melanic offspring where alleles were at the same locus, and very few realised that if the alleles occurred at separate loci, then no crosses would give all melanic offspring.

(d) This question was very well done with the vast majority of candidates completing the Lincoln index calculation successfully to give the population size as 87.

BIOLOGY

Paper 9700/51
Planning, Analysis and Evaluation 51

Key messages

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

When planning an investigation, it is important to set out the work in a logical way and ensure that all parts of the investigation are addressed.

Candidates should be given opportunities to analyse and evaluate a variety of experimental techniques, using statistical tests as appropriate.

General comments

Candidates should read the information given carefully before they begin to write their answer; key points can be underlined or highlighted for clarity. Responses should be precise when referring to time, for example, **Question 1(d)(i)** demonstrated the need for understanding of when to use statistical tests such as the *t*-test.

Question 2(a) showed the importance of carefully reading the question and making comparative statements, such as the use of the word 'only' when suggesting differences, in this case between two diversity indices. In **Question 2(b)(i)**, specific answers about when additional sampling should be carried out were required.

Comments on specific questions

Question 1

(a) (i) Candidates were usually able to correctly calculate the R_f value as 0.40 or give an answer that could be rounded to 0.4, taking account of minor differences in measurement. Answers that included a unit, such as cm, were not given credit.

(ii) Many candidates correctly identified the two photosynthetic pigments present only in *S. costatum* as fucoxanthin and diadinoxanthin. When calculating R_f values from chromatograms, candidates should measure to the centre of the spot of pigment.

(b) Candidates were asked to compare the expected rates of photosynthesis for the two species in blue, green and red light. Therefore, no credit was given to those candidates who simply compared the absorbance of the two species without linking this to the rate of photosynthesis. A few candidates described how the expected rate changed as the wavelength increased for each species; although, a comparison between the two species at the stated wavelengths was required for credit to be awarded.

Many candidates were able to gain full credit for a correct comparison of the expected rates of photosynthesis in blue light and red light. To also gain credit for green light, candidates needed to pay closer attention to the data in **Fig. 1.4**. *S. costatum* had a faster expected rate of photosynthesis in blue and green light than *R. salina*; those candidates who achieved full credit noted that the difference between the expected rates for *S. costatum* and *R. salina* was less for green light than for blue light.

(c) (i) Candidates were asked to suggest one reason why using algal beads improved the validity of the investigation. Several candidates suggested that the beads would protect the algal cells from changes in pH or that the algal beads could be reused; these advantages apply to immobilised enzymes but are not relevant for this investigation. The strongest responses noted that the coloured algal cells would affect the colour of the hydrogencarbonate indicator solution. Algal beads can be separated easily from the hydrogencarbonate indicator solution, thus not affecting the measurements of absorbance. Credit was also given to candidates who suggested that algal beads allow more accurate standardisation of the mass/volume of the algae. References to size or surface area were not sufficient to gain credit.

(ii) Candidates were asked to state the two independent variables and the dependent variable in the investigation. A minority confused the independent and dependent variables. Several candidates correctly identified the independent variables as the species of algae and the colour of light. The investigation used blue, green and red filters as apparatus to change the independent variable; therefore, stating the independent variable as the 'colour of filter' was not sufficient to gain credit.

Credit was given to those candidates who stated that the dependent variable was the absorbance or the pH of the indicator solution. The dependent variable should be the variable that is measured in the investigation; therefore, the colour of the indicator solution, the rate of photosynthesis and the carbon dioxide concentration were not given credit.

(iii) Stronger candidates were able to describe a suitable method to investigate the effect of the three colours of light on the rate of photosynthesis in both species of alga. It was important that candidates read the information given on pages 8, 9 and 10 carefully. No credit was awarded for maintaining the temperature or for a risk assessment.

To fully describe the investigation, candidates needed to vary both the species of algal beads and the colour of light. Strong responses included a method for how the blue, green and red filters should be used. Correct methods included wrapping the filters around each bottle or placing the filters in between the light source and the bottle. Most candidates considered the variables that would need to be controlled in this investigation, such as the number of algal beads and the volume of hydrogencarbonate indicator solution. References to size or to the amount of solution should be avoided. Very few candidates noted that red hydrogencarbonate indicator solution should be used at the start of the investigation. Candidates should specify the method used to standardise light intensity: using a lamp at a fixed distance from the bottle of algal beads and carrying out the investigation in a dark room both gained credit. A buffer should not be used as the investigation measures the change in pH.

Stronger candidates correctly described the use of a control bottle, replacing the algal beads with something appropriate. Ideas for the control such as leaving the bottle in the dark or in white light were not creditworthy. Candidates should try to 'add value' to what is given in stem of the question. On page nine, candidates were told that the student 'removed a sample of the indicator solution from the small bottle'. Credit was not awarded for repeating this information, but details of how this could be done with a pipette or a syringe were creditworthy. The strongest responses included details of how to calibrate the colorimeter with distilled water before taking measurements.

The methods planned by many candidates stated the measurements that would need to be taken. Candidates should measure the absorbance of the hydrogencarbonate indicator solution after a set time. The algal beads should be left for at least 10 minutes to allow sufficient time for photosynthesis to take place. Phrases such as 'leave for, about/approximately 30 minutes' are imprecise and did not gain credit. Measuring the 'time taken for the colour of the hydrogencarbonate indicator solution to change' is not possible as the colour change would be both gradual and subjective. The algal beads should not be added to the hydrogencarbonate indicator solution and left to equilibrate as the photosynthesis and respiration of the algae will immediately cause the colour of the indicator solution to change. Most candidates recognised the need for replicates in the investigation and linked these to the calculation of a mean. The term 'average' should not be used in a scientific context. Credit was given to those candidates who stated that a minimum of three measurements should be used to calculate a mean for each colour of light and for each species of alga. A single mean should not be taken across the entire investigation; therefore, a precise description is required to avoid this misinterpretation.

(iv) The majority of candidates were able to identify a hazard of the investigation, a risk associated with that hazard and indicate the precaution that should be taken. For example, hydrogencarbonate indicator solution is an irritant and the candidate should wear gloves and eye protection. Hydrogencarbonate indicator solution is not corrosive, as this would prevent its safe use with living organisms.

(d) (i) Many candidates who gained credit referred to the data being continuous or the data showing a normal distribution. Using the *t*-test 'to compare two sets of data' is the correct idea; credit was only awarded if candidates also stated that the *t*-test is used to compare the means of two sets of data.

(ii) Candidates were often able to correctly state the null hypothesis. A few gave the alternative hypothesis or stated that there was 'no correlation' and therefore did not gain credit. Some responses incorrectly expressed the null hypothesis as 'there is no difference between the pH of *R. salina* and *S. costatum*'. The investigation measured the pH of samples of the indicator solution, rather than the pH of the actual algae.

Question 2

(a) This was the most challenging question on the paper. Stating that peat bog **A** had a higher Shannon index and peat bog **B** had a higher Simpson's index, with no additional information, was not sufficient to be credited. Candidates were asked how the differences in the data, shown in **Table 2.1**, may have led to the different conclusions. Some candidates used **Table 2.1** and stated that peat bog **A** had a higher number of species than peat bog **B** or that there were no individuals of species T, U, W, V in peat bog **B**. The strongest responses then made the connection between the higher number of species in peat bog **A** and the higher Shannon index for peat bog **A**.

Most candidates found it harder to describe the differences in the data as related to relative species abundance. Some responses stated that peat bog **B** had a higher total number of individuals, but very few candidates stated that peat bog **B** had a smaller range of species abundance than peat bog **A**. Where figures were quoted, candidates need to offer them as a data quote with a comparative evaluation to gain credit. Stating that peat bog **B** had 135 individuals in total and peat bog **A** had 99 individuals was not sufficient; it needed to be made clear that the total number of individuals in peat bog **B** was greater than in peat bog **A**. Phrases such as 'more individuals' or 'only 99 individuals' were helpful when making comparisons. Strong responses made the connection between the higher total number of individuals in peat bog **B** and the higher Simpson's index for peat bog **B**.

Those candidates who did not discuss either the Shannon index or the Simpson's index in their answer were able to gain credit for making a correct statement using **Table 2.1** about the number of species and the relative species abundance for the two peat bogs.

(b) (i) Candidates were asked to describe how the sampling method could be improved to make sure the results are more representative of all the invertebrates in the whole of peat bog **A**. Many candidates were aware that invertebrates may be nocturnal and used this to suggest correctly that sampling should be done at different times of the day, including at night. Similarly, several answers suggested sampling in different months or seasons. Imprecise responses were not creditworthy; stating that sampling should be done at more times or at more sites was not sufficient. The strongest responses stated that the sampling sites should not just be along the edge of the path. This could be achieved by using random coordinates to select sites in the whole of peat bog **A**. A larger quadrat would not make the results more representative as the sampling would still be along the edge of the path.

Candidates should consider whether each bullet point of the sampling method could be improved. Very few candidates suggested using an expert to improve the identification of the invertebrate species. Using a sweep net or a pitfall trap would allow motile invertebrates to be sampled more effectively than with a quadrat. A few candidates were awarded credit for a correct reference to mark-release-recapture as this would allow a more accurate estimate of the number of individuals of each species. Although, candidates sometimes provided too much detail about mark-release-recapture and did not address other aspects of the sampling method.

(ii) Successful candidates calculated *D* as 0.730 with correct working in **Table 2.2** and were therefore awarded full credit. Some candidates needed to use correct rounding.

(iii) The majority of candidates were able to use their answer from **Question 2(b)(ii)** to correctly conclude that peat bog **A** was more biodiverse than peat bog **B**. Simply comparing the *D* values without commenting on the biodiversity of the peat bogs was not sufficient.

BIOLOGY

Paper 9700/52
Planning, Analysis and Evaluation 52

Key messages

- It is important that candidates read the whole question prior to answering.
- Certain themes appear commonly, including planning an investigation and statistical analysis of data. Those candidates who have practised these skills are more likely to do well.
- When planning an investigation, it is important to set out the work in a logical way and for it to be detailed enough to let another person follow it.

General comments

Candidates were able to choose a suitable statistical test, calculate the rate of a reaction and draw a suitable graph with ease. Some candidates were challenged when providing an outline of an ecological method to collect suitable data.

Comments on specific questions

Question 1

(a) Candidates were asked to state two suitable control experiments as part of the preliminary experiment. Candidates should state only two control experiments, rather than list many, as those who did this often included variables which needed to be standardised or controlled, such as the lamp being placed at the same distance from the chloroplast suspension or maintaining the volume of chloroplast suspension. Candidates should be aware that control experiments are to check that it is the independent variable that is affecting the dependent variable, and not some other factor. Standardised or controlled variables are different to control experiments, these variables are things which need to be kept constant during the experiment.

(b) (i) Many candidates were able to successfully calculate the rate of the light-dependent stage of photosynthesis for each concentration of chloroplast suspension to one decimal place and attained full credit.

(ii) There were many graphs seen which attained full credit. Some candidates needed to develop their graph drawing skills to ensure that axis labels matched table headings, including units. The scale chosen should allow the graph to be read easily within half a square, with all graph points accurately plotted using a small cross or a small dot in a circle. The plotted points should be connected with a clear, sharp, unbroken line, in this case as a smooth curve or with ruled straight lines joining the points. No extrapolation of graph lines should have been present.

(c) This question asked why the procedure worked when 10% sucrose was used, but did not work when distilled water was used in step 1 of the preliminary experiment. Stronger candidates were able to make the link that the 10% sucrose solution must have had the same water potential as inside the chloroplast, therefore, water did not enter the chloroplast by osmosis and hence, the chloroplast did not burst. Some candidates realised that the question was about water potential, however, referred to water entering the leaf or the cell bursting when placed in distilled water, rather than the chloroplast.

(d) There were some clear and detailed plans which gained full credit, outlining a method that was set out in a logical order and detailed enough for another person to follow. Candidates needed to decide on a suitable concentration of chloroplast suspension from the preliminary results provided.

Many candidates successfully chose a range of temperatures to investigate which were evenly spread, with a minimum of 5 °C gap between temperatures. Almost all were able to correctly describe how to maintain each temperature, with the most common response being the use of a water bath. A few candidates described that the chloroplast suspensions needed time in the water baths to equilibrate. Lots of plans included reference to the lamp being placed the same distance away from the chloroplast suspension for each temperature.

Candidates were asked to include details about how they would take accurate results. The most successful responses referred to comparing the colour of the experimental tube, when the experiment had reached its end point, with a tube containing only chloroplast suspension. Candidates were asked to include more detail for steps 7, 8 and 9 of the preliminary method provided. Therefore, no credit was given to additional details referring to other steps in the experiment.

The majority of answers seen correctly referred to repeating the experiment at each temperature at least three times and then calculating a mean. Answers stating that they would repeat the whole experiment three times and calculate a mean were incorrect and did not gain credit. Some responses mentioned replicating at each temperature a suitable number of times, but this was sometimes linked to calculating an average. It is important that candidates use the term mean in scientific work.

Question 2

(a) (i) Candidates were asked to outline a method which could be followed to collect the data shown in **Fig. 2.3**. They could have described how to perform either a random or systematic sampling technique, or outlined how to perform the mark-release-recapture technique.

Those candidates who wrote about either the random or systematic sampling techniques, usually gained credit for use of a quadrat and gave a correct description of how this would be used. Successful answers included precise details about what measurements to record in each quadrat. Some candidates needed to develop their answer by stating that they would count the number of each phenotype of ladybird present in each quadrat, rather than just counting the number of ladybirds present.

Successful answers from candidates who outlined a mark-release-recapture technique, included details about counting the number of each phenotype of ladybird in their first capture and also the number of marked and unmarked ladybirds from each phenotype in their second capture. Many candidates gained credit for stating that the markings made on the ladybird should not be harmful, too obvious or should not be easily removed.

A number of candidates used the term species when describing what they would count, rather than phenotype. All ladybirds were of the same species; therefore, this did not gain credit.

(ii) This question asked for two pieces of extra information that the researchers should provide to improve confidence in their conclusion. The most common response was to carry out some form of statistical analysis on the data collected. Other successful responses included details such as the sample size and access to the missing data from **Fig. 2.3**.

As the question asked for information which would improve the confidence in their conclusion, candidates needed to be precise when stating that knowing the samples were taken at the same sampling sites, at the same time of day or that the duration of sampling was the same each time. Therefore, answers which just made reference to knowing when sampling took place or where, did not gain credit, as this could have been different each time samples were taken, and this information would not have improved the confidence in their conclusion.

(b) (i) Successful answers referred to the fact that the line on the graph was steeper for the melanic phenotype compared to the non-melanic phenotype.

(ii) Many candidates gave comparative answers to this question, and as such attained full credit. A few candidates just quoted data and needed to develop their answers by including comparative terms such as higher, faster, longer. These terms were frequently used by most candidates, allowing

them to successfully state two further conclusions from the graphs shown. Most candidates made full use of both graphs provided in **Fig. 2.4** and attained full credit for their answers.

(c) Most candidates successfully identified that either Pearson's linear correlation or Spearman's rank correlation were suitable statistical tests to use to analyse the relationship between mass of the ladybirds and maximum temperature difference. Some were able to justify this with suitable reasons for their specific choice of test. Candidates who stated that Pearson's linear correlation test was a suitable test, as the scatter diagram suggested a linear relationship, gained credit. Those who chose Spearman's rank correlation and referred to the scatter diagram suggesting an increasing relationship were also successful.

(d) Candidates were asked to outline a breeding experiment that could be carried out to test the hypothesis 'Some melanics are homozygous dominant, and some melanics are heterozygous' and to state the results they would expect if the hypothesis was supported.

Successful answers described many breeding pairs being used, with a pair consisting of a melanic ladybird and a non-melanic ladybird. Those candidates who then went on to describe the phenotypes of the offspring expected if the melanic parent was homozygous and the phenotypes of the offspring expected if the melanic parent was heterozygous, were the most successful. Many candidates just stated the offspring expected for a homozygous melanic parent or a heterozygous melanic parent and did not gain credit. There were some very detailed experiments outlined which included each breeding pair being kept separate from other breeding pairs and the offspring being separated immediately from the parents.

BIOLOGY

Paper 9700/53
Planning, Analysis and Evaluation 53

Key messages

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

When planning an investigation, it is important to set out the work in a logical way and ensure that all parts of the investigation are addressed.

Candidates should be given opportunities to analyse and evaluate a variety of experimental techniques, using statistical tests as appropriate.

General comments

Candidates should read the information given carefully before they begin to write their answer; key points can be underlined or highlighted for clarity. Responses should be precise when referring to time, for example, **Question 1(d)(i)** demonstrated the need for understanding of when to use statistical tests such as the *t*-test.

Question 2(a) showed the importance of carefully reading the question and making comparative statements, such as the use of the word 'only' when suggesting differences, in this case between two diversity indices. In **Question 2(b)(i)**, specific answers about when additional sampling should be carried out were required.

Comments on specific questions

Question 1

(a) (i) Candidates were usually able to correctly calculate the R_f value as 0.40 or give an answer that could be rounded to 0.4, taking account of minor differences in measurement. Answers that included a unit, such as cm, were not given credit.

(ii) Many candidates correctly identified the two photosynthetic pigments present only in *S. costatum* as fucoxanthin and diadinoxanthin. When calculating R_f values from chromatograms, candidates should measure to the centre of the spot of pigment.

(b) Candidates were asked to compare the expected rates of photosynthesis for the two species in blue, green and red light. Therefore, no credit was given to those candidates who simply compared the absorbance of the two species without linking this to the rate of photosynthesis. A few candidates described how the expected rate changed as the wavelength increased for each species; although, a comparison between the two species at the stated wavelengths was required for credit to be awarded.

Many candidates were able to gain full credit for a correct comparison of the expected rates of photosynthesis in blue light and red light. To also gain credit for green light, candidates needed to pay closer attention to the data in **Fig. 1.4**. *S. costatum* had a faster expected rate of photosynthesis in blue and green light than *R. salina*; those candidates who achieved full credit noted that the difference between the expected rates for *S. costatum* and *R. salina* was less for green light than for blue light.

(c) (i) Candidates were asked to suggest one reason why using algal beads improved the validity of the investigation. Several candidates suggested that the beads would protect the algal cells from changes in pH or that the algal beads could be reused; these advantages apply to immobilised enzymes but are not relevant for this investigation. The strongest responses noted that the coloured algal cells would affect the colour of the hydrogencarbonate indicator solution. Algal beads can be separated easily from the hydrogencarbonate indicator solution, thus not affecting the measurements of absorbance. Credit was also given to candidates who suggested that algal beads allow more accurate standardisation of the mass/volume of the algae. References to size or surface area were not sufficient to gain credit.

(ii) Candidates were asked to state the two independent variables and the dependent variable in the investigation. A minority confused the independent and dependent variables. Several candidates correctly identified the independent variables as the species of algae and the colour of light. The investigation used blue, green and red filters as apparatus to change the independent variable; therefore, stating the independent variable as the 'colour of filter' was not sufficient to gain credit.

Credit was given to those candidates who stated that the dependent variable was the absorbance or the pH of the indicator solution. The dependent variable should be the variable that is measured in the investigation; therefore, the colour of the indicator solution, the rate of photosynthesis and the carbon dioxide concentration were not given credit.

(iii) Stronger candidates were able to describe a suitable method to investigate the effect of the three colours of light on the rate of photosynthesis in both species of alga. It was important that candidates read the information given on pages 8, 9 and 10 carefully. No credit was awarded for maintaining the temperature or for a risk assessment.

To fully describe the investigation, candidates needed to vary both the species of algal beads and the colour of light. Strong responses included a method for how the blue, green and red filters should be used. Correct methods included wrapping the filters around each bottle or placing the filters in between the light source and the bottle. Most candidates considered the variables that would need to be controlled in this investigation, such as the number of algal beads and the volume of hydrogencarbonate indicator solution. References to size or to the amount of solution should be avoided. Very few candidates noted that red hydrogencarbonate indicator solution should be used at the start of the investigation. Candidates should specify the method used to standardise light intensity: using a lamp at a fixed distance from the bottle of algal beads and carrying out the investigation in a dark room both gained credit. A buffer should not be used as the investigation measures the change in pH.

Stronger candidates correctly described the use of a control bottle, replacing the algal beads with something appropriate. Ideas for the control such as leaving the bottle in the dark or in white light were not creditworthy. Candidates should try to 'add value' to what is given in stem of the question. On page nine, candidates were told that the student 'removed a sample of the indicator solution from the small bottle'. Credit was not awarded for repeating this information, but details of how this could be done with a pipette or a syringe were creditworthy. The strongest responses included details of how to calibrate the colorimeter with distilled water before taking measurements.

The methods planned by many candidates stated the measurements that would need to be taken. Candidates should measure the absorbance of the hydrogencarbonate indicator solution after a set time. The algal beads should be left for at least 10 minutes to allow sufficient time for photosynthesis to take place. Phrases such as 'leave for, about/approximately 30 minutes' are imprecise and did not gain credit. Measuring the 'time taken for the colour of the hydrogencarbonate indicator solution to change' is not possible as the colour change would be both gradual and subjective. The algal beads should not be added to the hydrogencarbonate indicator solution and left to equilibrate as the photosynthesis and respiration of the algae will immediately cause the colour of the indicator solution to change. Most candidates recognised the need for replicates in the investigation and linked these to the calculation of a mean. The term 'average' should not be used in a scientific context. Credit was given to those candidates who stated that a minimum of three measurements should be used to calculate a mean for each colour of light and for each species of alga. A single mean should not be taken across the entire investigation; therefore, a precise description is required to avoid this misinterpretation.

(iv) The majority of candidates were able to identify a hazard of the investigation, a risk associated with that hazard and indicate the precaution that should be taken. For example, hydrogencarbonate indicator solution is an irritant and the candidate should wear gloves and eye protection. Hydrogencarbonate indicator solution is not corrosive, as this would prevent its safe use with living organisms.

(d) (i) Many candidates who gained credit referred to the data being continuous or the data showing a normal distribution. Using the *t*-test 'to compare two sets of data' is the correct idea; credit was only awarded if candidates also stated that the *t*-test is used to compare the means of two sets of data.

(ii) Candidates were often able to correctly state the null hypothesis. A few gave the alternative hypothesis or stated that there was 'no correlation' and therefore did not gain credit. Some responses incorrectly expressed the null hypothesis as 'there is no difference between the pH of *R. salina* and *S. costatum*'. The investigation measured the pH of samples of the indicator solution, rather than the pH of the actual algae.

Question 2

(a) This was the most challenging question on the paper. Stating that peat bog **A** had a higher Shannon index and peat bog **B** had a higher Simpson's index, with no additional information, was not sufficient to be credited. Candidates were asked how the differences in the data, shown in **Table 2.1**, may have led to the different conclusions. Some candidates used **Table 2.1** and stated that peat bog **A** had a higher number of species than peat bog **B** or that there were no individuals of species T, U, W, V in peat bog **B**. The strongest responses then made the connection between the higher number of species in peat bog **A** and the higher Shannon index for peat bog **A**.

Most candidates found it harder to describe the differences in the data as related to relative species abundance. Some responses stated that peat bog **B** had a higher total number of individuals, but very few candidates stated that peat bog **B** had a smaller range of species abundance than peat bog **A**. Where figures were quoted, candidates need to offer them as a data quote with a comparative evaluation to gain credit. Stating that peat bog **B** had 135 individuals in total and peat bog **A** had 99 individuals was not sufficient; it needed to be made clear that the total number of individuals in peat bog **B** was greater than in peat bog **A**. Phrases such as 'more individuals' or 'only 99 individuals' were helpful when making comparisons. Strong responses made the connection between the higher total number of individuals in peat bog **B** and the higher Simpson's index for peat bog **B**.

Those candidates who did not discuss either the Shannon index or the Simpson's index in their answer were able to gain credit for making a correct statement using **Table 2.1** about the number of species and the relative species abundance for the two peat bogs.

(b) (i) Candidates were asked to describe how the sampling method could be improved to make sure the results are more representative of all the invertebrates in the whole of peat bog **A**. Many candidates were aware that invertebrates may be nocturnal and used this to suggest correctly that sampling should be done at different times of the day, including at night. Similarly, several answers suggested sampling in different months or seasons. Imprecise responses were not creditworthy; stating that sampling should be done at more times or at more sites was not sufficient. The strongest responses stated that the sampling sites should not just be along the edge of the path. This could be achieved by using random coordinates to select sites in the whole of peat bog **A**. A larger quadrat would not make the results more representative as the sampling would still be along the edge of the path.

Candidates should consider whether each bullet point of the sampling method could be improved. Very few candidates suggested using an expert to improve the identification of the invertebrate species. Using a sweep net or a pitfall trap would allow motile invertebrates to be sampled more effectively than with a quadrat. A few candidates were awarded credit for a correct reference to mark-release-recapture as this would allow a more accurate estimate of the number of individuals of each species. Although, candidates sometimes provided too much detail about mark-release-recapture and did not address other aspects of the sampling method.

(ii) Successful candidates calculated *D* as 0.730 with correct working in **Table 2.2** and were therefore awarded full credit. Some candidates needed to use correct rounding.

(iii) The majority of candidates were able to use their answer from **Question 2(b)(ii)** to correctly conclude that peat bog **A** was more biodiverse than peat bog **B**. Simply comparing the *D* values without commenting on the biodiversity of the peat bogs was not sufficient.