BIOLOGY

Paper 9700/11
Multiple Choice

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

General comments

The paper differentiated well.

Comments on specific questions

Questions 1, 5, 10, 17, 27, 29, 35 and 40

At least half of all candidates answered these questions correctly.

Question 2

The functions of microtubules and centrioles were poorly understood, with less than half of all candidates answering correctly.

Question 3

Almost half of the weaker candidates incorrectly indicated that the ribosomes in mitochondria and chloroplasts are 80S.

Questions 4, 9, 22 and 23

More than half of all candidates answered these questions correctly.

Question 6

Approaching a quarter of the weaker candidates were able to use the test results to determine which substances were present.

Question 7

More than a quarter of the weaker candidates could correctly identify β-glucose.

Question 8

Almost three quarters of the stronger candidates answered this correctly. Less than a quarter of the weaker candidates selected each option almost equally in this question.

Question 11

More than a quarter of all candidates correctly identified the statement describing the tertiary structure.

Question 12

Over a quarter of all candidates incorrectly selected option **D**. If students have carried out experiments on the breakdown of hydrogen peroxide, they should realise that it can break down on its own.

Question 13

Over a half of the weaker candidates incorrectly suggested that the substrate is the same shape as the active site.

Question 14

Less than a quarter of the weaker candidates correctly identified the graph.

Question 15

More than a quarter of all candidates correctly carried out the numerical processing required to give the most accurate estimate of the ratio.

Question 16

Almost a quarter of all candidates incorrectly suggested that both facilitated diffusion and active transport require ATP.

Questions 18, 19, 20, 21, 25, 26, 28 and 37

Almost three fifths or more of the stronger candidates answered these questions correctly.

Question 24

More than three quarters of all candidates answered this question correctly.

Question 30

Approaching half of all candidates were able to correctly give the sucrose concentrations and water potentials.

Question 31

More than a quarter of all candidates incorrectly selected options **B** or **D**. The arrow labelled 3 represents diffusion of sucrose through plasmodesmata.

Question 32

Over half of all candidates incorrectly suggested that arteries pump blood out of the heart. It is the ventricles that pump the blood out of the heart.

Question 33

Over a half of the weaker candidates confused the role of the atrioventricular node with the Purkyne tissue.

Question 34

Most of the stronger candidates answered this question correctly.

Question 36

Over a quarter of all candidates understood the importance of the chloride shift.

Question 38

Almost a half of all candidates incorrectly suggested that all four events could explain how bacteria become resistant. Event 4 is not correct.

Question 39

More than a quarter of all candidates answered this question correctly.

BIOLOGY

Paper 9700/12
Multiple Choice

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

General comments

The paper differentiated well.

Comments on specific questions

Questions 1 and 7

Less than a quarter of the weaker candidates selected each option almost equally in these questions.

Questions 2, 18, 20, 23 and 34

Approximately three quarters of the stronger candidates answered these questions correctly. About a quarter or less of the weaker candidates answered correctly.

Questions 3, 6, 16 and 36

Three quarters or more of all candidates answered these questions correctly.

Question 4

Whilst most stronger candidates answered correctly, over half of the weaker candidates incorrectly selected options containing mitochondria and/or the nucleus. Neither of these are found in prokaryotes.

Question 5

Most stronger candidates appreciated that both DNA and RNA viruses would contain adenine and cytosine, but not thymine.

Question 8

A quarter of weaker candidates answered this correctly. Many weaker candidates incorrectly suggested that fructose or glucose was a disaccharide.

Questions 9, 11, 12, 14, 17, 19, 21, 24, 25, 27, 30, 31 and 40

Over three quarters of the stronger candidates and at least a third of the weaker candidates answered these questions correctly.

Question 10

Whilst most stronger candidates answered correctly, over half of the weaker candidates incorrectly indicated that statement 1 was correct.

Question 13

Just over half of all candidates answered correctly. The correct option 2, an increase of substrate concentration, was missed by a third of all candidates.

Question 15

Over half of all candidates incorrectly selected options containing function 3. Glycoproteins on the surface of a cell surface membrane do not secrete specific chemicals used for cell signalling.

Question 22

Whilst almost three quarters of the stronger candidates answered correctly, very few of the weaker candidates answered correctly.

Question 26

Half of all candidates correctly identified X as a companion cell.

Question 28

Most stronger candidates knew what occurs in the apoplast and symplast pathways and answered correctly, whilst over three quarters of the weaker candidates answered incorrectly.

Question 29

Approximately a quarter of the weaker candidates were able to identify **D** as the incorrect statement.

Question 32

Most stronger candidates and nearly a quarter of the weaker candidates correctly identified the monocyte. A quarter of the weaker candidates incorrectly identified the red blood cell as a monocyte.

Question 33

Just over a quarter of all candidates answered correctly. Over a half of all candidates incorrectly selected either option **B** or option **C**. Vessel R cannot be a capillary since it would have a lumen of 2 mm which is about 280 times larger than the actual lumen of a capillary.

Question 35

Most stronger candidates answered correctly. Almost a half of the weaker candidates incorrectly selected option **D**. The closure of valves in veins would not prevent backflow into ventricles.

Question 37

This was answered correctly by nearly half of all candidates.

Question 38

Over a quarter of candidates correctly understood that treating severe cases with antibiotics would control the spread of cholera and TB.

Question 39

Half of all candidates realised that all three effects were correct. The antibodies initially produced following vaccination can be long lived (a number of years) or the memory cells formed following vaccination have the ability to respond to future infections.

BIOLOGY

Paper 9700/13
Multiple Choice

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

General comments

The paper differentiated well.

Comments on specific questions

Questions 1, 6, 7, 16, 22 and 23

Over three quarters of all candidates answered these questions correctly.

Questions 2, 4, 5, 8, 9, 17, 19, 20, 21, 31, 32, 33 and 39

Over a half of all candidates answered these questions correctly.

Question 3

Three quarters of the stronger candidates and nearly a third of the weaker candidates answered correctly. Less than half of all candidates incorrectly selected option **C**.

Question 10

Over a quarter of the weaker candidates were able to recognise that all four features are correct for triglycerides and phospholipids.

Question 11

Most stronger candidates and less than a quarter of weaker candidates realised that the quaternary structure was being described.

Question 12

A quarter of all candidates were able to process the information provided and realised that all three conclusions could be made.

Question 13

Over a quarter of the weaker candidates answered this question correctly. Candidates who were able to recall carrying out similar experiments understood that the volume of oxygen released each 30 seconds would decrease due to substrate being converted into product.

Question 14, 18 and 25

Approximately a quarter of the weaker candidates selected each option almost equally in these questions.

Question 15

A third of all candidates realised that statement 2 was correct, whilst over nine tenths of all candidates selected options containing feature 3. Virtually half of the weaker candidates incorrectly suggested that ATP was involved in both processes.

Question 24

Over three quarters of the stronger candidates and approaching a half of the weaker candidates could correctly process the information provided.

Question 26

Over a half of the weaker candidates were unable to correctly select the statement describing the photomicrograph.

Question 27

A common misconception amongst the weaker candidates was that statements 1 and/or 2 described properties of water important for transport in xylem.

Question 28

Less than a quarter of the weaker candidates were able to identify xerophytic adaptations that cause a reduction in the water potential gradient between the leaf surface and atmosphere.

Question 29

A quarter of all candidates were able to successfully interpret the diagram to identify source and sink.

Question 30

Less than half of all candidates appreciated that all three items would be changed if mitochondrial activity was inhibited.

Question 34

Over half of the weaker candidates incorrectly selected option **A** or **B**. This cannot be correct since the right atrium is contracting to push blood into the right ventricle.

Question 35

This was answered correctly by almost half of all candidates.

Question 36

Just over half of all candidates could interpret the diagram correctly.

Question 37

A quarter of weaker candidates were able to process the information correctly.

Question 38

This question was answered very poorly. Nearly three quarters of all candidates incorrectly selected option **A** or **C**. Knowledge of the structure of bacteria should have led candidates to realise that neither of these options, including mitochondria, could be correct.

Question 40

Over three quarters of the stronger candidates, and less than a half of the weaker candidates answered correctly.

BIOLOGY

Paper 9700/21
AS Level Structured Questions

Key messages

The introductions to questions provide information that can be used by candidates to help them formulate their responses. If a response contains only copied information, it will not gain credit. For example, in **Question 2b(ii)**, candidates were informed that shark antibodies are smaller than human antibodies. Candidates who stated this fact as their answer to the question that followed, were only credited if the answer was qualified with further details.

Candidates should make sure that they are familiar with all the biological terms in the syllabus. **Question 5(c)(ii)** asked candidates to suggest how the permeability of the tonoplast changes during the development of xylem vessels. Some candidates could have improved their response if they had had a better understanding of this term. In **Question 5(d)**, candidates who were confident with using the terms pathogen and transmission gained most credit.

It is important that all candidates practise interpreting data in a wide range of forms. **Fig. 6.2** in **Question 6(b)** displayed results of a scientific investigation in a graphical form. Some candidates found this graph challenging to interpret because it had two *y*-axes with a different variable and scale on each.

General comments

The advantages of the electron microscope over the light microscope were well known by most candidates in **Question 1(b)**. Some candidates could have improved their interpretation of the electron micrograph in **Question 1(a)(i)** with further development of this skill area.

Candidates should read questions carefully to ensure they answer the question asked. **Question 2(a)(iii)** asked candidates to describe differences in the structure of blood vessels. Many wrote about differences in the roles of these blood vessels, such as the transport of oxygenated and deoxygenated blood.

Care should be taken with the spelling of biological terms. Some candidates were unable to gain credit for their identification of base **X** in **Question 3(b)(i)** because this was not spelled correctly. Spelling was also important in **Question 5(d)(ii)** when stating the name of the organism that causes malaria.

Question 4(c) required candidates to apply their understanding of protein structure and how enzymes work, to the role of an enzyme in the influenza virus. The strongest candidates were able to use knowledge of the lock and key hypothesis to explain the importance of maintaining the shape of the active site. Candidates should practise applying their understanding of concepts in novel contexts to help them develop the skills needed to answer questions like this.

Comments on specific questions

Question 1

(a) (i) Strong candidates identified both organelles correctly. Many candidates found this question challenging. **A** was incorrectly identified as the nucleus in many responses. Candidates should carefully consider scale and the relative sizes of organelles when interpreting electron micrographs. The nucleus is a very large organelle relative to the size of other organelles in the cytoplasm, and so **A** could not be the nucleus. The presence of visible cristae in the mitochondrion should have helped candidates deduce the identity of this organelle. Organelle **B** was identified correctly by a larger proportion of the candidates. A common error was to name the organelle endoplasmic

reticulum without qualification of the type or to incorrectly identify **B** as smooth endoplasmic reticulum. This was not accepted because ribosomes were clearly visible on the surface of **B**. The abbreviation RER was not accepted as candidates were asked to name the organelle.

(ii) The majority of candidates who gained credit for the question linked a function of the smooth endoplasmic reticulum, such as lipid synthesis, to the enzymes attached to the membrane. Some candidates successfully linked their knowledge of immobilised enzymes to the enzymes in the membrane, stating advantages of immobilised enzymes such as greater stability. The strongest candidates thought carefully about how enzymes work and linked this to the enzymes in the membrane, stating ideas such as the active site of the enzyme being held facing the lumen. Candidates who simply stated the role of an enzyme in a reaction, such as acting as a catalyst or speeding up a reaction, were unable to gain credit. This is because the question asked for advantages of enzymes attached to the membrane rather than being free in the lumen.

(b) This was a straightforward question for many candidates. Most were able to identify an advantage of using the transmission electron microscope, such as greater magnification. Some candidates stated that greater detail could be seen. This needed to be related to the greater resolution of the microscope. Many candidates successfully named organelles that would be visible because of the greater resolution of the images. Some candidates stated that more organelles would be seen without naming them and needed to give further detail for this idea. Several candidates included values for the resolving power of each type of microscope and some of these were correct.

Question 2

(a) (i) The majority of candidates successfully described double circulation, making clear reference to the idea of blood flowing through the heart twice and the idea of this occurring during one complete circuit of the body. Full credit was given for descriptions of the pulmonary and systemic circulations. Fewer candidates were able to state why the human circulatory system is described as a closed system, with weaker answers stating that blood stayed in the body without referring to blood vessels.

(ii) Many candidates were able to identify the blood vessels **Q** and **R**. Some identified them only as a vein and an artery without naming the vein as the vena cava and the artery as the aorta, so these answers did not gain credit. Weaker candidates confused the blood vessels, identifying **Q** as an artery and **R** as a vein, or they incorrectly identified the blood vessels as either the pulmonary artery or the pulmonary vein.

(iii) The strongest answers showed application of knowledge of the structure of an artery and a vein to **Q** and **R**. Most candidates who gained credit described the difference in the thickness of the artery wall with the stronger answers stating this relative to the width of the lumen. Some candidates referred to smaller or thinner blood vessels without linking this description to the thickness of the wall or the diameter of the lumen, and these answers were not able to gain credit. The strongest responses included further detail about the blood vessel wall such as more elastic fibres. Some candidates needed to read the question more carefully as they wrote about the different roles of the blood vessels in the transport of oxygen; these answers were unable to gain credit as the question asked for differences in the structure of the blood vessels.

(b) (i) Candidates were required to apply their knowledge of the structure of a human antibody to the unfamiliar shark antibody described in the question. The strongest answers recognised that the shark antibody did not have the two light chains found in the human antibody. Weaker answers confused the quaternary structure of haemoglobin with that of an antibody, making reference to alpha and beta chains rather than heavy and light chains. Some candidates confused levels of protein structure describing the tertiary structure and shape of the molecule rather than the quaternary structure and the number of polypeptide chains in the molecule.

(ii) The most common correct reason for the greater success of shark antibodies was the idea that the smaller size of the antibodies allowed them to reach more of the cells in the tumour. Candidates explained this in a variety of ways, such as passing through small spaces between cells in the tumour to reach cells at the centre. The best answers developed ideas in more detail, explaining that as the antibodies were smaller, more antibodies might be able to pass through the gaps in the capillary wall. The strongest candidates referred to antibodies entering the tissue fluid once they had passed through the capillary wall.

(iii) There were some very good answers to this question and many candidates demonstrated their understanding of artificial passive immunity. Some candidates confused this with active immunity and described how the injection would stimulate the production of antibodies in the person. Most candidates who recognised that this was an example of passive immunity were able to link the idea to the advantage of the injection as fast-acting. Fewer candidates went on to explain how the antibodies in the injection were able to protect from the pathogen, such as the idea of antibodies binding to the non-self antigen on the surface of the pathogen.

Question 3

(a) (i) Most candidates were able to explain that globular proteins are spherical in shape. Fewer were able to develop their answer further to give other properties of globular proteins such as solubility in water. The strongest responses linked solubility in water to the tertiary structure of the enzyme, carefully describing the position of the amino acids with hydrophilic R groups and those with hydrophobic R groups. Sometimes these descriptions lacked important details such as reference to amino acids and simply described hydrophilic and hydrophobic areas or regions. Some candidates confused the structure of a protein with the structure of a phospholipid. Here, they described hydrophilic heads and hydrophobic tails. Some candidates described the quaternary structure of the protein, which was not relevant to the question asked.

(ii) Candidates answered this question well, with many able to describe the reaction catalysed by carbonic anhydrase and identify the product, carbonic acid. Weaker responses made reference to transport of carbon dioxide in the blood or the diffusion of carbon dioxide into red blood cells without reference to the reaction catalysed by carbonic anhydrase. Some candidates recognised the role of the enzyme in a reaction involving carbon dioxide and needed to develop this further by identifying the other reactant as water.

(b) (i) Many candidates approached this question with confidence, correctly identifying base **X** as guanine. Candidates should take care with the spelling of biological terms, as some answers were unable to gain credit because the base was spelled incorrectly. The most common error was to name the base adenine. Most candidates were able to give evidence to support the identification of guanine, with the majority recognising the double ring and classifying the base as a purine. Those gaining full credit recognised the significance of the three hydrogen bonds. Some candidates were unable to gain credit for this idea as they needed to state that the hydrogen bonds formed between complementary bases.

(ii) The effects of a mutation on protein structure were well known, with most candidates recognising that this would cause a change in the primary structure of the protein. Detailed responses went on to recognise the significance of the deletion and the resulting frameshift mutation. The strongest answers demonstrated a clear understanding that this frameshift would affect every triplet after the mutation. Some candidates could have improved their responses by clearly stating the effects of the mutation on the protein, such as an altered tertiary structure or a shortened polypeptide chain. Many candidates recognised that the protein produced as a result of this mutation may be non-functional.

(iii) This question required candidates to apply their knowledge of introns and of mutation to the unfamiliar scenario of a mutation in an intron. Many stated that there would be no effect on protein structure due to RNA splicing and introns not being found in mRNA that is transcribed at the ribosome. The most common error was to suggest that the mutation would alter the order of the bases in the mRNA produced and therefore the protein translated at the ribosome.

Question 4

(a) (i) There were some very good answers to this question with many candidates recognising that the virosome did not have any genetic material. Some answers confused the terms genetic information and genetic code. Many candidates realised that the virus had a capsid which was not present in the virosome. The most common incorrect answer was to suggest that viruses did not have phospholipid bilayers. This was not able to gain credit because candidates should know that some viruses do have an outer envelope made of phospholipids.

(ii) To answer this question successfully, candidates needed to recognise the importance of the phospholipid bilayer. Many were able to suggest this was significant and the best answers developed this idea by linking the properties of the components of a phospholipid molecule to the

central aqueous area. Stronger responses explained that the hydrophilic phosphate heads would face the aqueous central area while the hydrophobic fatty acid tail would face away from the central area. Candidates who described both hydrophilic heads and hydrophobic tails without reference the phosphate group or the fatty acids were still able to gain credit for their ideas.

(b) Candidates were required to use the information provided in the question stem to help them to answer this question. They were told that haemagglutinin is found in both the influenza virus and the virosome and asked why haemagglutinin is present in virosomes. There were some very good answers in which candidates accurately described the primary immune response, highlighting the activation of specific B-lymphocytes by antigen presenting cells and the formation of memory cells. The very strongest candidates identified haemagglutinin as a non-self antigen; some identified it as an antigen and did not gain credit as the recognition of the antigen as non-self is imperative to the initiation of an immune response. Some candidates wrote general statements about the vaccine providing protection from the influenza virus without reference to an immune response. These answers were not able to gain credit.

(c) The most successful answers linked knowledge of protein structure with an understanding of how enzymes work. These answers recognised the importance of the shape of the active site in allowing the substrate to bind to it, and the need for this to occur to enable the virus to leave the host cell and be transmitted to other cells. In order to draw these conclusions, candidates had to recognise that any change in the primary structure of the enzyme could change the tertiary structure and therefore the shape of the active site. Some candidates gained credit for recognising the importance of the substrate binding and were not able to develop their answer further to gain full credit.

Question 5

(a) This was a straightforward question for many candidates. Most were able to recall the names of the two pathways that water can take when crossing the root to the xylem tissue. The most common incorrect answer was to confuse the two pathways, writing apoplast rather than symplast and vice versa. Many candidates wrote a clear outline of the apoplast pathway, following the description given in the question of an outline of the symplast pathway. Weaker answers gave outlines which were too general, such as movement of water through cells, and these answers were not able to gain credit.

(b) This question was answered well by most candidates. The most common incorrect answers were identifying cells in a region of the vascular bundle above the xylem tissue or cells in the cortex.

(c) (i) This question was well answered, with many candidates identifying the lysosome. The most common mistake was to suggest the nucleus or mitochondrion.

(ii) Candidates needed to think carefully about the information in the question in order to suggest changes in the cell that might lead to the rupture of the tonoplast. Many candidates recognised that the tonoplast would increase in permeability and the strongest responses understood the importance of permeability to water. Some candidates wrote about the movement of water into the tonoplast rather than into the vacuole. Many candidates gained credit for recognising that an increase in pressure would cause the rupture of the tonoplast; some of these needed to link this idea to an increase in pressure in the vacuole for further credit. Weaker answers did not make the link between the tonoplast and the vacuole in the cell and instead wrote about the whole cell rupturing due to the increase in pressure.

(iii) The strongest responses recognised that the question asked how enzymes can be activated and described changes to the enzyme that could result in an inactive enzyme changing so that it worked effectively. The most common correct idea was a change in the shape of the active site so that it would become complementary to the substrate. Many candidates misinterpreted the question and wrote about the optimum pH of the enzyme without any suggestion of how the change in pH would change the enzyme to enable it to become active.

(d)(i) There were some very good answers to this question and many candidates demonstrated their understanding of an infectious disease. Strong responses made effective use of the information provided in the question and explained transmissibility by describing how the insect vector was moving from tree to tree causing the trees to develop symptoms of disease. Some candidates

could have improved their responses by referring to the bacterial pathogen which caused the disease rather than simply describing the disease being transmitted from one plant to another.

(ii) Strong answers were able to identify the type of organism that causes malaria as a protoctist. These answers often went on to provide an accurate binomial name for a species of *Plasmodium* that causes malaria. Credit was given for the genus name *Plasmodium* without a species name as the question did not specifically ask candidates to name the species. The most common incorrect answer was to state that malaria was caused by a mosquito and to name the mosquito as *Anopheles*.

Question 6

(a) (i) Many candidates answered this question with confidence, correctly identifying the stage of mitosis as anaphase. The most common error was to name the stage as metaphase.

(ii) Knowledge of the roles of mitosis was generally good, with many candidates able to state that mitosis is used for growth of the plant. Some went on to suggest other roles such as repair of tissues and asexual reproduction. Reference to the production of genetically identical cells was made by a small number of candidates. Some candidates stated that mitosis produces new cells. This was not given credit and the answer needed to be developed either to identify the cells produced as genetically identical to the daughter cell or to state a role for these cells, such as tissue repair or replacement of dead cells. Some candidates incorrectly stated that mitosis is used to repair cells.

(b) This question required careful data analysis. Many candidates were able to state the relationship between the change in the concentration of Paclitaxel and each of the two dependent variables. Some candidates found interpreting the graph with two *y*-axes challenging and confused the two trend lines. These candidates were given partial credit for their interpretation of the relationship between the variables. The strongest candidates used data from the graph to support their description of the relationships they identified. These responses showed deep thinking about the data and included suggested explanations for the relationships that were described. The most common suggestion was that the cells were stopped in metaphase. Some candidates used their knowledge of mitosis to suggest mechanisms for this, such as sister chromatids being unable to separate.

BIOLOGY

Paper 9700/22
AS Level Structured Questions

Key messages

When a question includes an instruction to 'name', candidates should be aware that they need to use a specific term in their answer to gain credit. In **Question 1(a)**, it was common for candidates to describe the pulmonary circulation and the systemic circulation, rather than to name them.

Care must be taken when providing a definition of a gene. When trying to interpret **Table 3.1** to formulate a response for **Question 3(c)(i)**, some candidates referred to a gene coding for an amino acid, rather than a polypeptide or protein, or stated that a gene is a sequence of amino acids, rather than a sequence of nucleotides.

A common misconception highlighted in **Question 4(b)(i)** was to think that the bronchiole epithelium and alveolar epithelium was the equivalent of the wall of the bronchiole and the alveolar wall. This meant that candidates gave some correct features of the two different epithelia but also included other details of the wall, for example mentioning elastic fibres and smooth muscle. This frequently resulted in some confused ideas and incorrect statements.

General comments

Some of the longer questions in this paper were assessing knowledge and understanding of two or three different syllabus topics. The strongest candidates were confident in applying knowledge from the different topics to answer these questions. In addition, these candidates planned their responses so that enough correct ideas were included to make sure that maximum credit could be given. The short answers required for **Question 1** were well attempted. Candidates needed to add more ideas to improve the quality of their responses to questions requiring extended answers. It was quite common to see sentences within a response that were not finished or that contained an obvious contradiction to an earlier statement.

Question 1(c) asked candidates to add label lines and letters to identify a described artery (pulmonary artery) and a described valve (tricuspid valve). When identifying the location of the tricuspid valve, some candidates needed to be more careful in making sure that the label line ended at the valve and not at one of the chordae tendineae or the spaces between these.

In **Question 2**, knowledge of viral structure was a weak area for many. Candidates should be familiar with the basic structure of enveloped and non-enveloped viruses. Only some knew that the correct term for the viral protein coat is 'capsid' and that the subunits of the capsid (the capsomeres) are composed of protein. In addition, only some candidates were able to deduce that the HCMV virus shown in **Fig. 2.1** had an outer envelope as part of its structure. In **Question 2(f)** and **2(g)**, stronger responses showed skill in being able to apply knowledge to the unfamiliar context presented. Others relied on recalling knowledge of the topic and, for example, gave facts about the mitotic cell cycle and a strong immune response, rather than considering what would be the situation if the mitotic cell cycle stopped or if an immune response was not strong.

Question 3(c)(ii) assessed the skill of drawing conclusions from information provided. Candidates were provided with enough information to help them understand an investigation into the survival rate of different cultures of trophozoite and were then asked to state the main conclusions that could be drawn from a table of results. Several candidates gave comparative data extracted from the results in **Table 3.2**, which was not accompanied by any explanations, and these could not gain credit.

It is important that candidates are practised in the identification of the different tissues of the gas exchange system from prepared slides, diagrams and photomicrographs, as well as becoming knowledgeable on the

distribution of the tissues in the different structures in the system. In **Question 4(b)**, several candidates incorrectly suggested that cartilage is located in the bronchioles.

In **Question 5(a)**, it was important for candidates to know the difference between a collagen polypeptide, a collagen molecule and a collagen fibre. In this question, candidates were only required to give a response relating a collagen polypeptide to a collagen molecule. Some gave details extending to a collagen fibre.

In **Question 6(b)**, some candidates wrote 'phloem sieve' or 'phloem sieve tube' in **Table 6.1** for event **A**. It is important for candidates to know that a phloem sieve tube should not be considered a single cell and that the full term 'phloem sieve tube element' should be used when naming the cell type that is part of a phloem sieve tube.

Comments on specific questions

Question 1

(a) Pulmonary circulation was the best known of the two circulations. The systemic circulation was extremely frequently named as the systematic circulation, which was not credited. Many correctly named the main vein as 'vena cava', with some giving more detail of superior and/or inferior vena cava (venae cavae). Pulmonary vein was the most common incorrectly named blood vessel.

(b) Many were clearly able to give a correct answer to name the type of blood vessel connecting capillaries and veins; far fewer could spell 'venule' correctly. A very wide range of incorrect spellings was seen.

(c) The names of the two described structures of the heart were not needed in this question. It was important for the label lines to end clearly at the correct structures and that candidates followed the instruction to add **L** or **R**. Label **L** (pulmonary artery) was more often correct than label **R** (tricuspid valve). Candidates need to use label lines. A proportion of candidates wrote the letter in precisely the correct location. Letters written close to the structure were not given credit. It was quite common to see the label line for **R** ending at the semilunar valve of the pulmonary artery, which suggested that some candidates did not interpret 'the right ventricle is in systole' as 'the right ventricle contracts.'

(d) Most followed the instruction to include the molecular formula for two of the missing terms in this passage about carbonic anhydrase and the production of hydrogencarbonate ions. 'Globular' was well known as the term for the overall spherical shape of the enzyme. Some gave 'tertiary' or 'intrinsic', terms which are associated with proteins and did not fit this context. 'Intracellular' was usually correctly known, although care was required in spelling this because 'interacellular' could not be credited as it was too close to intercellular, which has a very different meaning. For the next two gaps, common incorrect responses were 'oxygen' or 'carbonic acid' instead of 'water (H_2O)', and 'hydrogen carbonate' instead of 'carbonic acid'. 'Hydrogen ions' was usually known, although the molecular formula was sometimes incorrect, with H^-, H^{2+} and H stated.

Question 2

(a) Capsomeres were not required to be named in this question. Some candidates misread the first part of the question and gave a structural term for **S** rather than considering the chemical compound used to make the subunit of **T**. In addition to protein, amino acids and polypeptides were accepted. The term capsid was given by many to name structure **T** and those who stated protein coat were also credited. In the text the capsomere was simply termed 'structure **S**' and described as a subunit of **T**, so any responses stating capsomere in addition to capsid or protein coat were not credited. Several candidates incorrectly spelled capsid as 'caspid' and this was not credited. Weak responses gave structural details of bacteria or eukaryotic cells, for example giving peptidoglycan for the chemical compound or nucleus for structure **T**.

(b) The conversion of the actual diameter of HCMV from micrometres to nanometres was generally correctly carried out. Some incorrectly divided by 1000 to arrive at an answer that should have been recognised as a diameter that was far too small, even for a virus. Many of those who gave an incorrect answer attempted to use standard form.

(c) Candidates who applied knowledge of the role of DNA polymerase in semi-conservative replication gained credit in this question. It was acceptable to suggest the general process or provide detail, such as the formation of phosphodiester bonds between adjacent nucleotides. It was not correct to suggest phosphodiester bond formation between complementary bases. Some made the mistake of describing a role of RNA polymerase. Unwinding of DNA was not credited as this is a function of DNA helicase.

(d) The text described HCMV virions as different shapes, with structure **T** as always having the same shape. Those candidates who knew that some viruses have an outer envelope and could see on **Fig. 2.1** that the capsid was surrounded by an outer layer, realised that the change in shape was due to the flexible nature of the envelope. Ideas based on the arrangement and quantity of the tegument proteins were also accepted as sensible suggestions. The most common incorrect suggestions were based on mutations or on different tertiary structure glycoprotein shapes.

(e) In addition to having a good knowledge of bacterial structure, strong responses showed an understanding of what was meant by genetic material and displayed an ability to make correct comparisons. The information in **Fig. 2.1** provided all the details that were required for the genetic material of HCMV, and this needed to be compared to a typical bacterial cell. Many needed to follow the instruction to state one similarity and one difference. Some gave incorrectly matched comparisons, for example comparing the shape of DNA with the number of strands in a DNA molecule. It was evident that some needed to refer to **Fig. 2.1A**, where the genetic material was clearly stated as double-stranded, not single-stranded, and that the nucleic acid was DNA, not RNA. In **Fig. 2.1A**, the molecule was shown as linear and not circular. Many of the weakest responses seemed to interpret the term 'genetic material' as 'general structure' and many answers included details of bacterial structure, such as 70S ribosomes and peptidoglycan cell walls.

(f) Many candidates realised that, in the presence of UL69, the S and G2 phases of interphase following on from G1 were not going to occur, or that the other parts of the cell cycle (mitosis and cytokinesis) would not occur. An absence of the S phase was commonly and correctly linked to an absence of DNA replication. Points about changes to growth of the cell, or the increase in organelles in preparation for cell division, were less frequently made. An error made in some responses was to suggest that UL69 did not allow events in the G1 stage to occur, which led to cell death. Some suggested that mutations would occur, leading to uncontrollable mitosis or that only some of the phases of the cell cycle would be possible.

(g) Many candidates did very well on this question. Responses of a high standard used the correct terminology, considered events sequentially and wrote about a weak immune system rather than no immune system. The idea of a slower secondary immune response was noted by many. Those who correctly named one or more cell types of the immune system that would be fewer in number, usually went on to explain at least one consequence of this, most commonly a decrease or delay in antibody production. Weaker responses gave some of the functions of immune system cells and matched these incorrectly with the wrong cell type. Viral replication was sometimes described erroneously as mitosis or cell division. A small number of candidates only described the secondary immune response of a healthy person and needed to state that this would not be the case for a person with a weak immune system.

Question 3

(a) A proportion correctly gave protoctist as the type of organism causing malaria. Of these, some spelled the term correctly. Protozoa was seen on occasion and was also credited. *Plasmodium* as a genus and *Plasmodium falciparum* were in the introduction to **Question 3** and answers that included these or another *Plasmodium* species name were rejected. Incorrect answers included 'parasite', 'bacteria', 'virus' or the species name of a causative organism of a different infectious disease. A number gave 'mosquito' or *'Anopheles'.*

(b) (i) Good responses included the fact that there would be a greatly decreased risk of *Plasmodium* resistance occurring against the effects of all the drugs used in ACT. Most of those who gained full credit also pointed out that drugs would have different targets or that, even if resistance to one drug was evident, the other drug or drugs used would eliminate the pathogens. Fewer noted that it was unlikely for all the different mutations to occur that were needed for full resistance, or that, if all pathogens were destroyed, alleles or genes for resistance would not be passed on to offspring. Weak responses repeated the information provided in the bullet points or suggested that one or both drugs caused a mutation to occur and so conferred resistance.

(ii) A proportion of candidates remained focused on the disease malaria and showed an understanding that the transmission of the malarial pathogen involved *Anopheles* and the presence of the pathogen in the blood of the infected person. Some also understood that partial artemisinin resistance, compared to no resistance, would mean that the pathogen would be present in the body of the infected person for a longer time. This would allow more time when any blood taken by mosquitoes would be infected and could be passed on and would also allow the numbers of the pathogen within the infected person to increase. Very few explained that another outcome would be the increase in the number of mosquito vectors carrying the resistant pathogen. Many needed to consider the mode of transmission and gave vague answers explaining that the infected person could pass on the pathogen to uninfected people.

(c) (i) Some candidates were precise in comparing a gene and a gene mutation and were also successful in applying this to the examples given in **Table 3.1**. Others knew that a gene coded for a polypeptide or protein. They could have improved their answer by also explaining that a gene was a sequence of nucleotides and that a change in this sequence resulted in a gene mutation and the altered protein. Some candidates gave mutation C580Y as an example, which was not part of the question. Weak responses referred to *kelch13* being thymine, or coding for phenylalanine, describing the mutation as a change to adenine and producing a different amino acid, isoleucine. These responses needed to take into account that the gene is a length of DNA and not just one nucleotide, and that protein PfK13 consists of a chain of amino acids rather than just one. A common misconception was that the amino acids in **Table 3.1** were synthesised as part of the process of protein synthesis.

(ii) Candidates were provided with the results of mean percentage survival rate of six different cultures of *Plasmodium* trophozoites when exposed to two different concentrations of a therapeutic drug. Some candidates had no difficulty in identifying from the results in **Table 3.2** the number of different factors that could affect trophozoite survival and gave conclusions based on:

- the effect of different concentrations of DHA
- the different responses of strain **A** and strain **B** to DHA
- the different responses to DHA of cultures with mutations compared with cultures without mutations
- the different responses to DHA of the two cultures with different mutations.

Some responses contained statements that were only part way to a conclusion. For example, making statements about strain **A** that inferred a comparison to strain **B**, but without giving more detail related to strain **B**. Other responses made a statement about the cultures with mutations and using comparative terms and needed to explain that the comparison was with the cultures without mutations. Some could have expanded the terminology used to describe the effect of DHA on the survival rate of trophozoites so that they were clearly writing about lower or higher survival rates. Examples included stating that the 700 nmol dm^{-3} concentration of DHA was 'efficient' or 'better' or 'successful'. Several candidates described the results in **Table 3.2** rather than giving conclusions. Also, some candidates referred to DHA concentration instead of percentage survival rates, which resulted in some very confused answers. Some confused the variables involved in the investigation and stated that the mutations were being caused by the difference in concentrations.

Question 4

(a) There were several different ways candidates explained how mucus in the respiratory bronchioles would affect gas exchange and most gained credit for this. Some realised that these bronchioles would have a very narrow lumen as they were closest to the alveoli, which would compound problems. Some candidates also suggested these particular bronchioles may not have the cilia that would be able to move the mucus away from the alveoli. The most common incorrect suggestion and explanation was that the airways further away from the respiratory bronchioles have mucus and cilia and would trap all the potentially harmful agents, so that mucus would not be required to be present.

(b) (i) Some gave three or more clear comparative statements to describe the differences between the epithelia of bronchioles and alveoli. The presence of cilia in bronchioles and absence in alveoli was well known, as was the fact that squamous epithelial cells are present in alveoli. Few knew that bronchioles have columnar, or columnar and cuboidal epithelial cells. Most paid attention to the

instruction not to give differences in the number of goblet cells. Although many stated that alveolar epithelium was thinner than the epithelium of bronchioles, the comparison given was frequently incorrect because the epithelium of bronchioles was stated or implied to be many layers thick, or that mucus caused it to be thicker. Many responses did not show understanding that epithelium is the tissue layer facing the lumen of the airway and that the other tissues, such as smooth muscle and elastic tissue, were part of the wall of the bronchiole. Some responses also referred to cartilage, which is not located in the wall of the bronchiole.

(ii) Tissue **X** was named by many candidates as smooth muscle. It was not enough to state 'muscle'. Credit was given to those who related the ability of smooth muscle to contract and relax to a change in airway diameter. Responses stating that the bronchiole contracted did not gain credit. Some correctly named tissue **X** but then gave functions of elastic tissue or cartilage. It was a common error to describe smooth muscle as expanding or stretching or recoiling. Credit was available for outlining a correct function if elastic tissue was wrongly named as the tissue. Limited credit was available for a correct function if tissue **X** was named as cartilage because this tissue is not located in bronchioles.

Question 5

(a) Most noticed that glycine occurred as every third amino acid in the section of polypeptide chain shown in **Fig. 5.1** and explained that glycine was the smallest amino acid. To gain full credit, more detail was required relating these structural details to a molecule of collagen. Some gave clear descriptions of the tight coiling that could be achieved to obtain the triple helix. Others knew that a molecule of collagen was composed of three polypeptides and needed to go on to explain that they formed a triple helix. Some incorrectly described strong covalent bonding between polypeptides or described the polypeptides as being parallel to each other in a staggered arrangement, confusing the structure of a collagen fibril or fibre with the structure of a collagen molecule. Weak responses wrote about alpha-helices and beta-pleated sheets, and gly was sometimes termed glycogen or glycerine.

(b) Many began their answer by explaining that collagen is packaged into a Golgi vesicle, or gave a description of a vesicle budding off from the Golgi body. Fewer knew the role of microtubules in moving the Golgi vesicle to the cell surface membrane or explained that ATP is required. Good answers usually described the fusion of the Golgi vesicle to the cell surface membrane before release of collagen. This is preferable to using the term 'cell membrane', which could be referring to a membrane within the cell. Some candidates described collagen as moving to the cell surface and passing through transport proteins, and others suggested that active transport would occur.

(c) (i) Some candidates showed an understanding that, if collagenase was described as a hydrolytic enzyme, its activity would result in the breakdown of collagen. This helped them realise that if the activity was prevented by the presence of a collagenase inhibitor, collagen breakdown would not occur. Many candidates incorrectly stated that collagen would decrease in the extracellular matrix.

(ii) A greater proportion correctly stated the effect of a non-competitive inhibitor on the V_{max} of collagenase than the effect on K_m. Many suggested that K_m would increase.

Question 6

(a) Strong answers gave clear statements about the solvent properties of water related to xylem sap and phloem sap and went on to explain how water contributed to this transport. Many gave correct examples of solutes transported. Some described the cohesive and adhesive properties of water molecules and related this to the transpiration stream in xylem vessels. Fewer explained how water was important in the hydrostatic pressure gradient that was created for mass flow in phloem. Some only mentioned mass flow without relating this to the pressure gradient. Weaker answers confused the two different transport mechanisms. Some listed properties of water that were not relevant to the question relating to water and the transport of xylem and phloem sap.

(b) Candidates who did well in **Question 6(a)** generally also gained full credit in **Question 6(b)**. Most knew that sucrose moves into a companion cell through cotransporter proteins. The cells involved in events **A** and **B** were less well known.

BIOLOGY

Paper 9700/23
AS Level Structured Questions

Key messages

Question 1(b)(iii) produced a range of answers of differing quality. Some responses incorrectly described peptide bonds as one way of holding the three-dimensional structure of the protein shown in **Fig. 1.2** in place, while others only named hydrogen bonds. When describing how the three-dimensional structure of a protein is held in place, a strong response would:

- name the types of bonds that are present
- state that these bonds are the result of interactions between R groups of amino acids in the polypeptide chain
- outline details of each of the types of interaction that occur.

Candidates need to be precise when explaining the functions of cell organelles. In **Question 2(a)(ii)**, some explained that lysosomes break down pathogens or worn-out organelles, which was not accurate enough to gain credit. To improve on this, responses should explain that lysosomes are organelles, which contain hydrolytic enzymes that function to carry out this breakdown.

The use of abbreviations in a response is not always appropriate. If an abbreviation has been given in the stem of a question, then it is acceptable to use this within a response. There are occasions when the entire term needs to be used in an answer. For example, in **Question 6(d)**, candidates were asked to 'State the name of the compound indicated by **X**'. The response required here was haemoglobinic acid, which gave evidence that the actual term was known, rather than using the abbreviation HHb.

General comments

Many candidates read the question material very carefully, which helped them to construct responses that answered the question and enabled them to use the information given to construct a suitable answer. Others could have benefited from taking this methodical approach. For example, in **Question 1(b)(iii)**, many responses included disulfide bonds in the answer even though candidates had been told that the protein shown in **Fig. 1.2** has no cysteine residues. Stronger responses often stated that there are no disulfide bonds.

Candidates should also pay careful attention to the command word, number of marks available for each question and to any instruction to refer to the stimulus material in the question, such as graphs and tables. In **Question 2(a)(i)**, many candidates stated that macrophages 'engulf bacteria' without explaining how this occurs. The word 'engulf' was used in the question so could not be credited.

Question 3(b) proved to be the most challenging for the candidates. Simply describing the data or explaining the effect of changes in light intensity and wind speed on rates of transpiration did not answer the question.

There were many instances where candidates needed to use technical terms more carefully, and as a result credit could not always be given. Candidates should also pay careful attention to spelling, particularly for technical terms, such as the stages of mitosis. The term 'frameshift' was used by many candidates throughout **Question 5(b)**. The addition or deletion of a nucleotide (base) pair in DNA leads to a frameshift mutation – a change in the sequence of bases. The term is not used for the effect on the polypeptide produced as a result of this type of mutation.

Question 2(b)(i) involved a calculation that required candidates to work out a percentage change. When answering this question, many candidates did not realise that as the numbers of cases of TB decreased

between 1993 and 2018, they should indicate this by writing 'decrease' or giving a minus sign before their calculated value.

Comments on specific questions

Question 1

(a) (i) Many candidates successfully completed the diagram showing the formation of the peptide bond. The main error was to omit the water formed during the reaction. Some candidates did not understand what was required and wrote their answers using the boxes on the left of **Fig. 1.1** instead of using the space on the right, which was directly below the drawing of the cysteine molecule to be added to the elongating polypeptide. A common error was to show the peptide bond as C–O–N or C–H–N, rather than C–N.

(ii) Peptide was the most common answer. Some candidates gave other bonds that are found in other biochemical polymers, such as glycosidic, ester and phosphodiester. 'Polypeptide' bond was not accepted.

(iii) Most candidates gave ribosome as the organelle where the reaction shown in **Fig. 1.1** occurs. Rough endoplasmic reticulum was also accepted. The use of the abbreviations RER and ER was not credited. Cytoplasm was given by some candidates. This was too general and was therefore not accepted.

(b) (i) The secondary structures alpha helix and beta pleated sheet were given by many candidates. Some candidates needed to make it clear that they were writing the letter beta (β) as they often wrote 'B pleated sheet'. These answers did not gain credit. A very few stated that the diagram of the bacterial protein shows regions of no fixed shape.

(ii) There were some excellent answers to this question on the distinction between the tertiary and the quaternary structure of proteins. Strong answers stated that the protein is composed of a single polypeptide and not composed of two or more polypeptides. These went on to explain that in tertiary structure there are bonds between R groups of amino acids in the polypeptide chain to form the specific structure, whereas in quaternary structure there are intermolecular bonds between the polypeptides. Some candidates stated that the bacterial polypeptide does not have a prosthetic group, which is another reason why it does not have quaternary structure.

(iii) Candidates who had read this question carefully did not include disulfide bonds as part of their answer. Many others stated that disulfide bonds contributed to the three-dimensional structure of the protein shown in **Fig. 1.2**, even though the information given in the text stated that the protein does not contain the amino acid cysteine. Few candidates gave the details of the hydrogen bonds that stabilise the secondary structure and few gave the details of the bonds between R groups of amino acids that stabilise the tertiary structure. If these details were missing, then some credit could be awarded for references to hydrogen bonding and the interactions or bonds between R groups of amino acids.

Question 2

(a) (i) There were many good descriptions of how macrophages engulf bacteria. A common error was to continue the answer to describe the fate of phagocytic vacuoles (phagosomes) once inside the macrophage. Detail of the mechanism of attraction of the macrophage to the bacteria was also often included, and this was not needed for a description about engulfing bacteria. Candidates often referred to the role of lysosomes, which was not relevant to this question. Some answers referred to antigens being engulfed rather than making it clear that there are antigens on the surface of the bacteria. The strongest responses showed knowledge of the role of antibodies binding to antigens on the surface of the bacteria, so were able to describe the subsequent binding to the antibody receptors on the cell surface membrane of the macrophage. A few candidates referred to membrane fusion after describing the cytoplasm surrounding the bacteria.

(ii) Many candidates could have improved their response by explaining that hydrolytic enzymes contained within lysosomes are responsible for the breakdown of bacteria or other pathogens. A few responses referred to the role of lysosomes by relating hydrolytic enzymes to the breakdown of organelles that are non-functional, and there were some that referred to autolysis and apoptosis.

There were also some references to using the fragments of bacteria in antigen presentation. The lysosomal membrane preventing the release of potentially harmful enzymes into the cytoplasm was an important aspect that was described in a very few responses.

(b) (i) A range of answers (8 000 to 10 000) was accepted for the number of new cases in 2018. Many candidates read the figures correctly from **Fig. 2.2** and calculated a percentage change between 68 and 60. Many needed to indicate that the percentage change was a decrease. Almost all candidates presented their working in ways that could be followed.

(ii) Most answers stated that the number of new cases had decreased. Fewer went on to describe the steepest decrease between 1993 and 2001 or the constant numbers between 2013 and 2018. Some candidates noted the slight increase in 2015.

(c) There were several successful approaches to this question. The most common was to state that calculating the number of new cases per 100 000 of the population allowed valid comparisons to be made between different countries, taking into account differences in population size or between different years. Other answers stated that standardising the figures provides data for following the progress of the disease and determining the effectiveness of control measures for TB.

(d) Candidates listed many reasons why it is proving difficult to reduce the number of cases of TB across the world. Some answers needed to make it clear that a bacterium is responsible for the disease. For example, answers such as 'TB is resistant to antibiotics' did not gain credit. References to the cost of vaccines and antibiotics did not gain credit. Some candidates also referred, incorrectly, to 'TB bacteria becoming immune to antibiotics'.

Question 3

(a) There were many good answers explaining how water moves up xylem vessels in the trunks of trees. Some candidates began their response in the soil and explained how water moves into root hairs, across the cortex and through the endodermis, often referring to the apoplast and symplast pathways. This was not necessary as the question made no reference to the absorption of water by the roots and its passage across the root to the xylem. Some candidates needed to make clear the distinction between the movement of water in xylem by cohesion and by adhesion. Some who knew the difference could have gone further and added that hydrogen bonds form between water and the cellulose in xylem vessel walls, or between water and the hydrophilic regions of lignin in the xylem wall. Some responses included how the structure of xylem is adapted for water movement and these did not gain credit.

(b) **Fig. 3.1** showed the results of an investigation into the effect of changes in photosynthetically active radiation (PAR) and wind speed on cavitation in tree trunks. Candidates were asked to suggest conclusions that could be made from the results. Some candidates simply described the data without giving any conclusions and others tried to explain the results rather than giving conclusions related to the data. The strongest responses stated that cavitation only occurs when light or PAR is available when the trees must be photosynthesising. Some candidates also concluded that if cavitation is occurring, this means that water must be moving in the xylem. Many candidates looked for relationships between PAR, wind speed and cavitation but described correlations that were not evident in the data. Very few made the simple conclusion that cavitation does not occur when the wind speed is below 1.25 $m\,s^{-1}$.

Question 4

(a) (i) Almost all candidates identified metaphase and anaphase correctly and most of these gave the correct spellings to gain credit. Telophase was a common incorrect answer for **B**.

(ii) There were many good descriptions of the role of microtubules in mitosis. Candidates stated that they form spindle fibres that are attached to centromeres and are involved in the orientation of chromosomes on the metaphase plate and moving chromatids (or daughter chromosomes) to the poles during anaphase. Some responses incorrectly stated that daughter chromosomes are pulled to the 'sides' or 'ends' of the cell, rather than the poles, or stated that microtubules are attached to centrosomes, rather than centromeres.

(iii) Most candidates knew that cell **C** would go through telophase and cytokinesis. No credit was awarded for mentioning telophase. They described the changes that occur to the nucleus and

cytoplasm and some described the role of the ring of microfilaments composed of actin in dividing the cell into two. Candidates needed to make it clear that a nuclear envelope re-forms around each group of chromosomes. Candidates who used the term 'nuclear membrane' did not gain credit as this means a single membrane only, and the term 'nuclear envelope' should have been given to show knowledge that the nucleus is a double membrane-bound structure.

(b) Candidates had mixed success in explaining the events that occur in the cell cycle that lead to daughter cells being genetically identical. Many realised that the question covered the whole of the cell cycle and not just mitosis. For this question, it was important to give the complete term 'semi-conservative replication of DNA' as this forms part of the explanation relating to genetically identical daughter cells. Some included unnecessary detail of base pairing. Strong responses used scientific terminology to help them gain full credit. Some answers could have been clearer that following semi-conservative replication, a chromosome is made of two genetically identical sister chromatids and that the daughter cells will each contain one chromatid from each chromosome. Some showed an understanding that a chromosome with two sister chromatids has two complete identical DNA molecules. In some responses it was evident that they were writing only about DNA in a single chromatid. Some mentioned checking errors occurring as a result of replication, and many of these could have improved by stating that these errors can be repaired.

Question 5

(a) (i) There were many good answers to this question on cell signalling. Most candidates assumed that there were receptors on the cell surface and that these have a shape complementary to the signalling compound LL-37. Some responses could have gained more credit by being clear that all the different cells would have the same receptor. Some candidates wrote about events that occur in target cells after the signalling molecule binds to the receptor. There was no extra credit for this. Some confused cell signalling with enzyme theory and induced fit.

(ii) Many candidates stated that endothelial cells of capillaries are thin and smooth with pores between the cells. It was not correct to state that these cells have 'thin cell walls' and it was not relevant to the question to state that they are 'one cell thick'. 'Flat' was ignored as these cells form the lining to cylindrical structures. There were some good descriptions of how the endothelial cell is wider in the region of the nucleus. Without further detail related to the structure of an endothelial cell, comparing the cell with a fried egg was not credited. Many candidates described the appearance of a capillary or the structure of capillary walls, rather than addressing the question asked.

(b) (i) Most candidates used **Table 5.2** to find out that the amino acid phe (phenylalanine) would be replaced by tyr (tyrosine) if there was a change to the triplet at position 5 shown in **Table 5.1**. Some wrongly identified ser or asp instead tyr.

(ii) Very few candidates wrote out the complete new sequence of amino acids; instead, it was more common to find answers which stated that the sequence of amino acids after the first position would be different. Many used the change from leu (leucine) to arg (arginine) as an example. The gain or loss of a nucleotide pair is the cause of a frameshift mutation. Some candidates incorrectly used this term to describe the subsequent change to the amino acid sequence (primary structure) of the polypeptide.

(iii) Some candidates made careful use of **Table 5.2** and noticed that the change in base sequence would lead to a stop codon (at position 4), so that a peptide composed of three amino acids is all that would be formed. Many stated that the third amino acid would still be gly (glycine). Weak responses often missed the point that a stop codon would be produced.

(c) Many candidates stated that the genetic code is universal because it is the same in all organisms. Some candidates were unsure so wrote 'in most organisms' or 'all plants and animals' and did not gain credit. Some suggested it is 'a code used across the world' implying an agreed academic code.

(d) Candidates who had made good use of the genetic code in **Table 5.2** gave good answers explaining that some amino acids, such as glycine, have more than one triplet. Other amino acids, such as phe and ser, were also used as examples. Fewer knew that the genetic code is degenerate. Some wrote 'degenerative' or 'degenerated'. These answers were not credited.

Question 6

(a) Many candidates stated that the ions cannot pass through the phospholipid bilayer or hydrophobic core of the membrane. Some also stated that the proteins are necessary for the facilitated diffusion of the ions. Some candidates misunderstood what was required and gave answers about electrical neutrality.

(b) A proportion of candidates showed a good understanding of the chloride shift shown in **Fig. 6.1**. Many weaker responses were more confused and explained the movement of chloride ions in terms of loss of carbon dioxide, rather than maintaining the electrical neutrality of the cell.

(c) There were a variety of correct answers to this question on the movement of carbon dioxide. Some candidates simply stated that carbon dioxide diffuses down its concentration gradient into the plasma. Some referred to a gradient in partial pressure and this was accepted as an alternative. Other candidates correctly stated that carbon dioxide is passing into the alveoli for excretion.

(d) Haemoglobinic acid is the compound indicated by **X** on **Fig. 6.1**. 'Haemoglobonic' was not accepted as an alternative. The abbreviation HHb was also not accepted. Haemoglobin was the most common incorrect answer.

BIOLOGY

Paper 9700/31
Advanced Practical Skills 1

Key messages

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

Candidates should be aware that the command word in the question indicates how they 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'. For example, **Question 1(b)(ii)** required candidates to 'Explain the change in water content of the melon cubes between 16 hours and 20 hours'. The candidates needed to give reasons why something happens, such as referring to the water potential in the cells of the melon cube being equal to the water potential of the sucrose solution, and that there would still be movement of water across the membrane of the cells but there will be no net movement of water.

General comments

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

Candidates should read the whole of each question before attempting it. This should help them to plan their time carefully and answer the questions accurately.

Comments on specific questions

Question 1

(a) (i) Most candidates stated a suitable volume of distilled water added to the large test-tube so that the liquid in the dialysis tubing was covered.

(ii) Many candidates correctly completed **Table 1.2** by stating three concentrations of ascorbic acid (e.g. 0.5, 1.0 and 1.5) and stating the correct volumes of **A** and **W** to make up these concentrations.

(iii) The majority of candidates organised their results clearly by presenting a ruled table. Stronger candidates included the heading for the concentration of ascorbic acid with units ($g\,dm^{-3}$) and the heading for volume of iodine with units (cm^3). Most candidates gained credit for recording a volume for each of the concentrations of ascorbic acid. Many candidates recorded results which showed that the higher the concentration of ascorbic acid, the greater the volume of iodine added. Stronger candidates recorded volumes in whole cm^3 or to no more than one decimal place.

(iv) Many responses correctly recorded the volume of iodine added to reach the end-point for the sample of the solution from the small beaker with the appropriate units.

(v) Many candidates correctly estimated the concentration of ascorbic acid in the solution outside the dialysis tubing bag using their own results.

(vi) Some candidates correctly calculated the rate of diffusion of ascorbic acid out of the dialysis tubing by showing their figure for the concentration of ascorbic acid divided by the time that the dialysis tubing had been left in the distilled water and used the appropriate units.

(vii) Some responses correctly identified two significant sources of error. These responses stated that the drops of iodine varied in volume and it was difficult to judge the end-point.

(viii) Some candidates correctly suggested two improvements. These included using a colorimeter, repeating the investigation at least twice and calculating the mean.

(b) (i) Most candidates used the headings given in **Table 1.3** to correctly label the *x*-axis (time / hours) and the *y*-axis (water content / g of water for each g of melon). Some candidates labelled the incorrect axis or gave incomplete headings. Strong candidates used a scale of 2.5 to 2 cm for the *x*-axis and a scale of 0.20 to 2 cm for the *y*-axis. Many candidates plotted all the points accurately and joined the points with a thin line. The most common errors were not using the correct scale and drawing lines which were too thick.

(ii) Some candidates correctly explained that there was no net movement of water between 16 hours and 20 hours and that the water potential in the cells of the melon cubes was the same as the water potential in the sucrose solution.

Question 2

(a) (i) Credit was awarded to candidates whose drawings did not include any cells and used most of the space provided. Candidates gained credit for carefully following the instructions and drawing the shaded region as shown in **Fig. 2.1**. Many candidates gained credit for drawing at least two layers of tissue and showed the correct subdivision of the vascular bundles. Many candidates drew the vascular bundle in the correct proportion to the outer layer of the stem. Most candidates used 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 xylem vessel elements with each vessel element touching at least one other and with double lines representing the walls. The most common error was to draw lines that did not meet up precisely or were too thick. Many candidates were credited for showing vessel elements with straight sides. Most candidates used a label line to show the cell wall of one xylem vessel element.

(b) (i) Some candidates measured the length of **X**–**Y** and the scale bar correctly, showed the length **X**–**Y** divided by the length of the scale bar and multiplied by 100. Many candidates stated the correct answer with the appropriate units.

(ii) Most candidates correctly added a labelled line to **Fig. 2.2** to identify a stoma.

(iii) Some candidates correctly identified one observable similarity between the trichomes in **Fig. 2.2** and the trichomes in **Fig. 2.3** such as both trichomes were narrower at the tip compared to the base.

Some candidates also correctly identified two observable differences between the trichomes in **Fig. 2.2** and the trichomes in **Fig. 2.3** by stating that in **Fig. 2.3** the trichomes appeared divided into segments while in **Fig. 2.2** the trichomes were not subdivided, and that the trichomes in **Fig. 2.3** were wider at the base compared to the trichomes in **Fig. 2.2**.

BIOLOGY

Paper 9700/33
Advanced Practical Skills 1

Key messages

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

Candidates should be aware that the wording of a question often indicates how they should respond. The word 'explanation' may imply reasoning or some reference to theory, depending on the context. It is another way of asking candidates to 'give reasons for'. **Question 1(b)(iv)** required candidates to 'Suggest an explanation for the trend you described in **(b)(iii)**'. Here the candidates needed to detail why something happens, such as referring to an increase in number of active sites, more effective collisions and the formation of more enzyme-substrate complexes.

General comments

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

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

Comments on specific questions

Question 1

(a) (i) The majority of candidates gave three other temperatures (e.g. 35, 40, 45 °C) in **Table 1.2** that they were going to use to show the effect of temperature on the activity of enzyme **E**.

(ii) Most candidates correctly explained that the test-tubes were left in the water-bath for 3 minutes so that the milk and calcium chloride solution could reach the same temperature as the water-bath.

(iii) The majority of candidates organised their results clearly by presenting a ruled table. Stronger responses included the heading for temperature with units (°C) and the heading for time with units (seconds). Most candidates gained credit for recording a time for each temperature. Stronger candidates recorded at least two times for each temperature. Many candidates recorded results which showed that at lower temperatures the time to reach the end-point was longer. Stronger candidates recorded the times in whole seconds.

(iv) Most candidates correctly stated that the independent variable was temperature.

(v) Many responses correctly suggested that a suitable control for the investigation was to replace the enzyme with water or to use boiled and cooled enzyme.

(vi) Strong responses described how they would modify the procedure to investigate the effect of changing the concentration of milk on the time taken to reach the end-point, by using the same temperature and using proportional dilution to make at least 5 concentrations of milk.

(b) (i) Most candidates used the headings given in the table to correctly label the *x*-axis (% enzyme concentration) and the *y*-axis (activity of enzyme / arbitrary units). Some candidates labelled the

incorrect axis or gave incomplete headings. The stronger candidates used a scale of 0.05 to 2 cm for the *x*-axis, and a scale of 20 to 2 cm for the *y*-axis. Many candidates plotted all the points accurately and joined the points with a thin line. The most common errors were not using the correct scale and drawing lines that were too thick.

(ii) Many candidates used their graph accurately to determine the activity of the enzyme when the enzyme concentration was 0.25%. They showed on their graph how they determined this value by drawing an intercept on the graph at this point.

(iii) Many responses correctly described the trend in the results by stating that as the enzyme concentration increased, the enzyme activity also increased.

(iv) Some candidates correctly explained that the trend in the results was because there was an increase in the number of active sites, leading to more effective collisions and an increase in the number of enzyme-substrate complexes.

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 responses gained credit for carefully following the instructions and drawing the shaded region as shown in **Fig. 2.1**. Many candidates gained credit for drawing at least two layers of tissue and at least two vascular bundles and adjoining tissues. Many candidates correctly showed the subdivision of the vascular bundles. Most candidates used a label line to correctly identify the xylem.

(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, two cells from the epidermis and two cells from below the epidermis. Most candidates drew each cell touching at least two of the other cells and with double lines representing the cell walls. The most common error was to draw lines that did not meet up precisely or were too thick. Some candidates drew the correct proportion of the four cells with the cells below the epidermis being deeper than the cells in the epidermis. Most candidates used a label line to show the cell wall of one cell.

(b) Strong responses organised the table for this question into three columns, with one column for features, one headed **Fig. 2.2** and one headed **K1**. Many candidates listed at least three observable differences such as there were more vascular bundles in **Fig. 2.2** than on **K1,** or that the vascular bundles in **Fig. 2.2** were scattered throughout the stem while on **K1** the vascular bundles were positioned close to the epidermis, or that the xylem vessels in **Fig. 2.2** were larger than on **K1**.

(c) (i) Most candidates clearly marked each of the vascular bundles counted in the quarter of the stem on **Fig. 2.3**. Some candidates correctly stated the number of vascular bundles in the quarter and showed this number multiplied by 4. Some candidates counted the vascular bundles in the other regions of the stem.

(ii) Most candidates correctly suggested why it is an advantage to the plant to have many vascular bundles in the stem. The responses included that it was to increase the transport of water and mineral salts throughout the plant, or to give the stem added strength and greater support.

BIOLOGY

Paper 9700/34
Advanced Practical Skills 2

Key messages

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

Candidates should be encouraged to read through the question paper so that they are aware of questions they need to answer about the procedure as they carry it out, such as 'describe one significant source of error when carrying out steps 8 to 17'. After carrying out the investigation and estimating the ascorbic acid concentrations of **U** and **C**, the candidate should be able to state additional concentrations of ascorbic acid that could be made to make the estimations for **U** and **C** more accurate.

Candidates should be aware that the wording of questions often indicates how the candidate should respond. When the question says 'describe one significant source of error' or 'identify three observable differences' the candidate needs to select their answers carefully and give the appropriate number of responses rather than an extended list.

When identifying a structure or describing observable differences, candidates should remember that only features that can be observed on the section or in the figure should be recorded, rather than those which in theory are present.

General comments

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

Candidates who had read the whole of each question before attempting it were more likely to be able to plan their time carefully and answer the specific questions accurately.

Comments on specific questions

Question 1

(a) (i) Most candidates were able to carry out a serial dilution by half of 0.1% ascorbic acid, showing the correct concentration below each beaker (0.05%, 0.025%, 0.0125% and 0.00625%) and transferring 10 cm^3 of the previous concentration to the next beaker and adding 10 cm^3 of distilled water to each beaker. Some candidates needed to include the appropriate number of decimal places when stating the concentrations below each beaker and some stated concentrations that were incorrect by a factor of ten.

(ii) The majority of candidates organised their results clearly by presenting a ruled table and included the heading for percentage concentration of ascorbic acid (**A**) and the heading for volume of iodine with units cm^3. Credit was gained for recording the volume of iodine for all the concentrations of ascorbic acid made, to the appropriate degree of accuracy for the apparatus used and recording results which showed that the volume of iodine for the higher concentration of ascorbic acid was greater than the volume of iodine for the lower concentration of ascorbic acid. A few candidates recorded the number of drops of iodine instead of the volume of iodine used and some candidates recorded the volume of iodine in whole numbers.

(iii) Some candidates correctly described one significant source of error as the difficulty in identifying the end-point. A very few candidates described the difficulty reading the syringe as the colour of iodine was too dark.

(iv) The majority of candidates correctly recorded the volume of iodine needed to reach the end-point for **U** and **C**. A few candidates incorrectly recorded the volume of iodine for **U** as less than the volume of iodine for **C**.

(v) Many candidates showed the correct positions on the scale bar of each percentage concentration of ascorbic acid made.

(vi) The majority of candidates that had correctly positioned each percentage concentration of ascorbic acid on the scale bar went on to use their results to estimate the concentrations of **U** and **C**. They showed their estimates by placing the letters **U** and **C** in the correct positions on the scale bar.

(vii) Most candidates correctly described using a wider range of concentrations with narrower intervals, with the stronger responses stating concentrations around the estimate for **U** and **C**. Some candidates suggested repeating the whole experiment and calculating a mean.

(viii) Many candidates recorded a lower volume of iodine needed to reach the end-point with **C** than with **U** in **Question 1(a)(iv)** and correctly suggested that ascorbic acid was broken down by heating. Some candidates recorded a higher volume of iodine needed to reach the end-point with **C** than with **U** in **Question 1(a)(iv)** and correctly suggested that water evaporated making ascorbic acid more concentrated. A few candidates recorded the same volume of iodine for **U** and **C** in **Question 1(a)(iv)** and correctly suggested that heating had no effect on the concentration of ascorbic acid.

(ix) Most candidates correctly outlined an investigation into different heating times on the concentration of ascorbic acid. Many candidates suggested using five different times and the stronger responses stated times evenly spaced with units. Many candidates stated that one concentration of ascorbic acid and the same temperature should be used. The most common error was to state five different temperatures.

(b) (i) The majority of candidates drew the graph, using the headings given in the table to correctly label concentration of ascorbic acid / mM on the *x*-axis and mass of *B. subtilis* / mg on the *y*-axis. They also used scales of 10 to 2 cm for the *x*-axis and 2 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 drawing a curve that did not accurately connect the points and extrapolating the line off the grid.

(ii) The majority of candidates correctly read off the figures at 10.0 mM and 35.0 mM from their graph. Most candidates showed the figure for 35.0 mM subtracted from the figure for 10.0 mM, divided by the figure for 10.0 mM and multiplied by 100. The most common error was dividing the difference by the figure for 2.5 mM instead of the figure for 10.0 mM.

Question 2

(a) (i) Credit was awarded to candidates whose drawings did not include any cells and used most of the space provided. Most candidates gained credit for carefully following the instructions and drawing a quarter of the stem. The stronger candidates gained credit for drawing two lines for the epidermis or endodermis and showing the correct position of the endodermis relative to the epidermis. Many 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 from the cortex, with each cell touching at least two of the other cells and with double lines representing the cell walls. The stronger candidates showed the different shapes of the cells. Most 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 four circular cells.

(b) (i) The majority of candidates correctly measured the diameter of the stem in **Fig. 2.2** using the line **X–Y** placed across the figure and showed the division of the measured diameter by 22. Most candidates correctly calculated the actual diameter of the stem and showed the appropriate units.

(ii) Most candidates correctly identified structure **B** as xylem and stated that it was identified as such because it had thick walls or it was hollow. Some candidates identified structure **B** correctly as it was facing the centre of the stem. The most common error was to identify structure **B** as xylem but to state the function of xylem instead of an observable feature that could identify the structure.

(iii) The majority of candidates identified at least two observable differences between **L1** and **Fig. 2.2** using only observable differences. Most candidates stated that there were fewer vascular bundles on **L1** and more in **Fig. 2.2** and that **L1** contained root hairs whereas **Fig. 2.2** did not. Some candidates stated that **L1** contained an endodermis and **Fig. 2.2** did not. Common errors were to include structures that were not observable, for example chloroplasts or mitochondria, or to refer to the whole section as a cell.

BIOLOGY

Paper 9700/35
Advanced Practical Skills 1

Key messages

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

Candidates should be aware that the wording of questions often indicates how the candidate should respond. When the question says 'state one significant source of error' or 'identify three observable differences' the candidate needs to select their answers carefully and give the appropriate number of responses rather than an extended list.

When describing observable differences, candidates should be reminded that only features that can be observed on the section or in the figure should be recorded, rather than those which in theory are present.

General comments

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

Candidates who had read the whole of each question before attempting it were more likely to be able to plan their time carefully and answer the specific questions accurately.

Comments on specific questions

Question 1

(a) (i) The majority of candidates were able to carry out a serial dilution by half of 6.0% hydrogen peroxide, showing the correct concentration below each beaker (3.0%, 1.5%, 0.75% and 0.375%) and transferring 10 cm^3 of the previous concentration to the next beaker and adding 10 cm^3 of distilled water to each beaker.

(ii) The majority of candidates organised their results clearly by presenting a ruled table and included the heading for percentage concentration of hydrogen peroxide (**H**) and the heading for time and seconds. Credit was gained for recording the time for all the concentrations of hydrogen peroxide made and recording results which showed that the time for the higher concentration of hydrogen peroxide was shorter than the time for the lower concentration of hydrogen peroxide. Many candidates recorded the time in whole seconds.

(iii) Most candidates correctly stated one significant source of error in the investigation as the difficulty in judging when the bead reached the top of the solution or that the beads were not all the same size. Some candidates stated that the beads stick to the side of the test-tube and a few candidates stated that the investigation was only carried out once.

(iv) The majority of candidates who had suggested the difficulty in judging when the bead reached the top of the solution in **Question 1(a)(iii)**, correctly suggested using a piece of black card behind the test-tube or drawing a line at the surface of the hydrogen peroxide so that it was easier to see when the bead reached the top of the solution. Candidates who had identified the variation in the size of the beads as an error, suggested ways to select beads of the same size. Many candidates suggested repeating the investigation and calculating a mean to improve the investigation.

(v) The majority of candidates correctly recorded a time for **U**. The most common error was not including the units.

(vi) The majority of candidates used their results from **Question 1(a)(ii)** and **Question 1(a)(v)** to correctly estimate the concentration of hydrogen peroxide in **U**.

(vii) Many candidates correctly described how to modify the procedure to investigate the effect of changing temperature on the time taken for the beads to rise. Some candidates correctly suggested using five different temperatures in thermostatically controlled water-baths. Some candidates correctly suggested keeping the concentration of hydrogen peroxide constant.

(b) (i) The majority of candidates drew the graph, using the headings given in the table to correctly label bead diameter / mm on the *x*-axis and percentage concentration of lactose after 5 minutes on the *y*-axis. They also used scales of 2 to 2 cm for the *x*-axis and 10 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 drawing lines point to point that did not accurately connect the points and extrapolating the line to 0.

(ii) The majority of candidates read off the correct value for the concentration of lactose in the milk after 5 minutes when the bead diameter was 5 mm from their graph.

(iii) Some candidates explained that as the bead diameter increased the total surface area of the beads in the syringe decreased. Many candidates explained that this led to fewer enzyme-substrate complexes being formed so less lactose was broken down to glucose and galactose. The stronger responses explained that a smaller total surface area meant that fewer active sites were in contact with the hydrogen peroxide so fewer substrates could bind to the active sites to hydrolyse lactose. Many candidates interpreted the graph incorrectly and suggested that lactose was the product of the reaction, so as the bead diameter increased there were more enzyme-substrate complexes formed and more lactose was produced.

Question 2

(a) (i) Credit was awarded to candidates whose drawings did not include any cells and used most of the space provided. Most candidates gained credit for carefully following the instructions and drawing the region of the stem indicated in **Fig. 2.1**. The stronger candidates gained credit for drawing three vascular bundles, each divided into at least three layers. Most candidates used a label line to correctly identify the region of the vascular bundle containing xylem.

(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 from the central tissue, with each cell touching at least two of the other cells and with double lines representing the cell walls. The stronger responses seen showed the different shapes of the cells. Most 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 four circular cells.

(b) The majority of candidates identified at least two observable differences between the section of the stem on **Fig. 2.2** and the section of the stem on **M1** using only observable differences. Most candidates stated that the vascular bundles in **Fig. 2.2** were present in a continuous layer around the section and were present as distinct vascular bundles on **M1**. They also stated that the shape of the stem in **Fig. 2.2** was a square whereas the shape of the stem on **M1** had many pointed ends. Many candidates stated that the stem in **Fig. 2.2** had a hollow centre whereas the stem on **M1** contained cells in the centre. Common errors were to include structures that were not observable, for example chloroplasts or mitochondria, or to refer to the whole section as a cell.

(c) The majority of candidates correctly measured the scale bar and the width of the stem in **Fig. 2.3** using the line **X–Y** placed across the figure. Most candidates correctly calculated the actual width of the stem and showed the appropriate units. The strongest responses showed all the steps in the calculation, for example, 253.5 μm divided by the measurement of the scale bar and the answer multiplied by the measurement of line **X–Y**. The most common error was not measuring the scale bar so the actual width of the stem could not be calculated.

BIOLOGY

Paper 9700/36
Advanced Practical Skills 2

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 should be able to show their calculations clearly, including all the steps involved in the calculation and their reasoning. **Question 2(c)(i)**, determining the mean actual diameter of a root, stated that the candidate needed to draw lines across the diameter of a photomicrograph. At least three lines should be drawn through the centre of the section so that the mean diameter can then be calculated. The answer should be shown to the correct degree of accuracy. Where the question states to show the answer to the nearest whole number, the answer to the calculation should be correctly rounded up to the nearest whole number.

General comments

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

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

Comments on specific questions

Question 1

(a) (i) The majority of candidates stated a suitable volume of water to put into the test-tube to cover the section of dialysis tubing containing the mixture.

(ii) The majority of candidates organised their results clearly by presenting a ruled table. Strong responses included the heading for time with units (minutes) and the heading for colour. The majority of candidates gained credit for recording a colour for every minute or until the end-point was reached for at least two consecutive minutes. Most candidates recorded colours as set out in **Fig. 1.1**.

(iii) Many responses correctly suggested three improvements to the investigation such as the use of a colour chart to better identify the colours, the use of a colorimeter, or using smaller intervals of time e.g. 30 seconds to take a sample from the test-tube.

(iv) Many candidates suggested a correct reason why it took longer to reach the end-point when starch was used as the substrate, by stating that the starch needed to be broken down before the action of yeast could release carbon dioxide. The stronger responses correctly suggested that as a result of using starch, there were fewer yeast enzymes available to hydrolyse the starch, fewer successful collisions between enzymes and substrate and fewer enzyme-substrate complexes.

(b) (i) Most candidates correctly stated that the independent variable was temperature.

(ii) Most candidates used the headings given in the table to correctly label the *x*-axis (time / minutes) and the *y*-axis (rate of carbon dioxide production / arbitrary units). Some candidates labelled the

incorrect axis or gave incomplete headings. Strong responses used a scale of 10 to 2 cm for the *x*-axis, and a scale of 1 to 2 cm for the *y*-axis. Many candidates plotted all the points accurately and joined the points with a thin line. The most common errors were not using the correct scale and drawing lines which were too thick.

(iii) Many candidates correctly described the trend by stating that as time increased the rate of carbon dioxide production increased. Stronger responses stated the time at which the rate of carbon dioxide production increased very rapidly, between 22 and 27 minutes, or when it stopped increasing, between 53 and 66 minutes. They also stated the rate of carbon dioxide production at these times with the appropriate units (au).

(iv) Most responses correctly stated the time required for the rate of carbon dioxide production to be 1.75 au according to their graph.

Question 2

(a) (i) Credit was awarded to candidates whose drawings did not include any cells and used most of the space provided. Strong candidates gained credit for carefully following the instructions and drawing the whole section of the root. Many candidates gained credit for drawing at least two layers of tissue and showed the correct proportion of the stele relative to the diameter of the root. Most candidates drew the outline of the xylem and used a label line to correctly identify the phloem.

(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 tissue in the cortex, with each cell touching at least two of the other cells and with double lines representing the walls. The most common error was to draw lines that did not meet up precisely or were too thick. Many candidates were credited for showing cells which had some straight sides. Most candidates used a label line to show an air space.

(b) Strong candidates identified and annotated three differences between the photomicrograph in **Fig. 2.1** and the section on **N1** by stating observable differences such as: **Fig. 2.1** had more vascular tissue than the section on **N1**, the vascular tissue in **Fig. 2.1** was spread out while the vascular tissue on **N1** was in the form a cross at the centre of the root, and the endodermis in **Fig. 2.1** was absent but was present on **N1**.

(c) (i) In order to calculate the mean actual diameter of the section on **Fig. 2.2**, strong candidates drew at least 3 lines across the diameter of the root passing through the black dot at the centre of the section, added these measurements together and divided the total by the number of measurements taken.

(ii) Many candidates showed the correct radius squared and multiplied by 3.14. Stronger responses also stated the answer to the nearest whole number and used appropriate units.

BIOLOGY

Paper 9700/41
A Level Structured Questions

Key messages

Candidates should make sure that they read each question carefully. To be successful candidates need to be able to interpret the question material, apply skills and recall learnt facts. Some of the skills tested in this paper were suggesting explanations in novel contexts (**Question 1** and **Question 3**), constructing reasoned explanations based on facts (**Question 2**, **Question 4** and **Question 5**), interpreting pictorial information (**Question 6**) and describing graphs (**Question 8** and **Question 9**).

General comments

Candidates should take time in the exam to check through answers to help avoid losing credit by contradicting themselves or writing ambiguously.

Comments on specific questions

Question 1

This question concerned the conservation of the wild Bactrian camel.

(a) Suggesting reasons why the wild Bactrian camel has become endangered was well attempted and many candidates scored full credit. As the species has become endangered (i.e. a change has occurred), candidates should have been thinking about what has changed in their environment to cause this, with changes likely to be linked to human activity. Habitat loss and competition with introduced domestic livestock are the major factors for this species. Candidates did not achieve credit for listing ecological principles, such as competition, predators and the ratio of births to deaths, without considering how these factors have changed as a result of human activity.

(b) While some candidates had a clear understanding of the role of the IUCN in nature conservation, many confused this supranational data collating agency with CITES, WWF and other organisations that play a more active role in habitat management and species conservation. Many candidates correctly described the role of the IUCN in assessing, listing and categorising endangered species; relatively few referred to the Red List of Threatened Species.

(c) In describing the process of embryo transfer, many candidates misused terminology. As well as confusing processes such as *in vitro* fertilisation and artificial insemination, some candidates confused the pairs of terms: ovum and embryo, zygote and embryo, uterus and ovary. Many candidates correctly referred to the idea of surrogacy with the wild Bactrian camel providing the embryo which would then be carried to full term by the less endangered dromedary camel. The practical details of carrying this out were less well described, with few responses mentioning screening embryos and freezing them for later use.

Question 2

(a) Most candidates could name a chloroplast pigment, although some wrote ‘chlorophyll alpha’ or ‘chloroplast a’ instead of chlorophyll *a*.

(b) Candidates struggled to explain what an absorption spectrum and an action spectrum show, although many were able to express the idea that the curves match or show the same pattern. While candidates frequently wrote about wavelengths of light, few realised that the absorption

spectrum shows how much of each wavelength is absorbed by a pigment, or that the action spectrum plots the rate of photosynthesis against the wavelengths in the spectrum of visible light.

(c) This was generally a well-answered question. Candidates needed to refer to the enzyme-controlled elements of photosynthesis and to explain how temperature increase would affect these reactions. Reference to kinetic energy and the formation of enzyme-substrate complexes helped to secure credit for some candidates. Some responses referred to the effect of temperature on the opening of the stomata rather than the direct effect on the reactions of photosynthesis.

(d) This was a straightforward question which was well answered in most cases. Candidates outlined the carboxylation and reduction steps of the Calvin cycle and linked triose phosphate to glucose or starch, and a few mentioned how glucose is polymerised to form the starch polymer from glucose monomers. Errors included stating that the three-carbon entity GP 'breaks down' to the similarly-sized entity TP and stating that reduced NAD rather than reduced NADPH was used along with ATP in this step.

Question 3

(a) (i) Candidates were asked to suggest and explain why the inner mitochondrial membrane remains intact when the organelle is placed in pure water. Candidates needed to describe a property of the inner mitochondrial membrane and link this to an explanation, generally involving the degree to which osmosis would occur. The most common correct suggestion was that the inner membrane is impermeable to water so water could not enter the matrix by osmosis. Some candidates mentioned that the inner membrane was folded, and a few went on to explain that this would allow the inner membrane to expand when the volume of the matrix expanded.

(ii) Successful responses described the roles of molecules like pyruvate, oxaloacetate, citrate and oxygen. Most candidates were unable to name three molecules that are in the matrix and are not coenzymes. Common incorrect suggestions were the coenzymes NAD, FAD, ATP and coenzyme A. Other incorrect suggestions were ions (e.g. H^+), organelles (e.g. ribosomes) and molecules that are situated on the inner mitochondrial membrane and not in the matrix (e.g. ATP synthase).

(iii) Candidates generally realised that cardiolipin prevents ion movement across the inner mitochondrial membrane and needed to go on to specify that it is hydrogen ions that must not be allowed to diffuse across, to maintain the proton gradient.

(b) (i) Candidates showed good recall and understanding of the events that establish a membrane potential across the inner mitochondrial membrane. Some candidates confused hydrogen ions with hydrogen atoms, and some confused the role of the H^+ ions with the role of the electrons. Most correctly stated that electrons pass down the electron transport chain and that this releases energy to pump the protons into the intermembrane space. Occasionally a candidate stated that the H^+ were pumped in the wrong direction into the matrix. Some answers finished early without relating the accumulation of protons to the establishment of the proton gradient, while others continued beyond the establishment of the gradient and described its use in driving ATP synthesis. A few candidates made the mistake of writing 'inner membrane space' rather than 'inter-membrane space'. Occasionally an answer referred to protons building up 'inside the inner membrane', implying within the phospholipid bilayer.

(ii) The majority of candidates were able to describe phosphate ions as moving via facilitated diffusion or through a carrier protein. Many were also able to link the movement of P_i with that of protons diffusing into the matrix.

(iii) Candidates found this question very hard to answer and very few scored credit. The idea of linking ADP and ATP transport mostly drew comments about efficiency of energy use rather than ensuring a constant supply of ADP so that ATP could continue to be made in the required amounts. Strong responses discussed the idea of ATP production being regulated.

Question 4

This question led the candidate through a sequence of developments in genetic manipulation, from the initial application of genetic engineering in making a recombinant protein in bacteria, to gene therapy in humans,

and then to the newer technique of gene editing. Many candidates could have improved their responses by distinguishing more carefully between these different landmark techniques.

(a) Answers often showed an incomplete or confused understanding of the main principles of genetic engineering. The context of the question was the use of recombinant DNA to produce a therapeutic protein. This context was often overlooked by candidates who focused on gene therapy of a human patient. The aspects of genetic engineering that were best known by candidates were the names and roles of the enzymes: restriction endonuclease, reverse transcriptase and DNA ligase. Less understood aspects were the separate stages involved in creating a recombinant plasmid and then inserting this recombinant vector into a new host cell, and also the need for transformed cells to show the expression of marker genes and for cloning the introduced gene.

(b) (i) Most answers referred to mitosis or cell division in multiplying the number of stem cells, and some went on to clearly describe the inheritance of the functional gene by the resulting daughter cells.

(ii) A large majority of candidates were able to explain that the purpose of a promoter is to allow gene expression by acting as the binding site for RNA polymerase or transcription factors. A small number confused RNA polymerase with DNA polymerase.

(iii) Candidates who gave very general answers, such as that the virus may cause side effects, did not gain credit. Stronger answers suggested that the virus could potentially cause immune responses or infectious diseases. Some candidates understood that random insertion of retrovirus DNA in the host cell genome might disrupt the expression of other genes. The overarching ethical issue being that a medical treatment should do less harm than good.

(c) Many candidates knew that Huntington's disease is caused by a dominant allele. Most candidates were familiar with the idea of gene editing. Answers were sometimes too general and did not apply to this particular example. Responses suggested that gene editing enabled the removal of the faulty allele, and many went on to state that this would be replaced with a normal allele. Relatively few responses explained that Huntington's disease is caused by extra repeats of the triplet CAG and that these extra repeats needed to be removed. The strongest answers explained that adding a normal recessive allele in this case would not work since the dominant allele is still present and being expressed.

Question 5

(a) This question required careful thought about the alpine habitat and an understanding of the question context. In this example there was no straightforward geographical isolation between two populations – candidates were told that the nearest islands were over 1500 km away to show that the new species originated on the South Island. Good responses described how plant species that initially grew at lower altitudes, adapted to higher ground through mutation and natural selection, forming new specialist alpine species. Candidates that demonstrated appreciation of the particular demands of the alpine mountain habitat, such as colder temperatures, thinner soil and strong winds, were more likely to gain credit in describing how mutation could aid plant survival and adaptation.

Despite the question stating that the alpine habitat is an area where trees cannot grow, many candidates referred to the alpine plants as trees. Candidates may not have noticed that the question referred to a large number of (different) alpine plant species, each one descended from a different starting lowland plant species in New Zealand. Some answers implied a large population of a single plant species (i.e. a large number of plants) developing due to lack of competition and herbivores in the mountains. Referring to different selection pressures causing mutation, lost some candidates credit. Candidates who relied on simple recall of past mark schemes about allopatric speciation did not achieve credit.

(b) (i) **Fig. 5.1** proved to be difficult for candidates to interpret correctly. The question was based on the idea that alpine plant species can only begin to develop when the mountains are higher than the treeline. Correct interpretation of **Fig. 5.1** showed that the mountains were consistently higher than the treeline from approximately 1 million years ago, and many candidates focused on the information that the current treeline is 1200 m and used this to give a wrong time figure from the graph.

(ii) Most candidates scored credit by writing that the DNA of the alpine species would need to be compared with some other DNA. A few realised that the correct comparison would be with the DNA of related lowland species. For example, a plant species in the same genus that grows at lower altitudes. Many responses suggested comparing with plants from millions of years ago which is not feasible. Some candidates suggested that similarities and differences in the DNA sequence should be counted and needed to go on to make clear the idea that the number of differences (mutations) relates to time due to the constant mutation rate (molecular clock idea).

Question 6

(a) Many candidates described points relating to artificial selection in general without focusing on the specific example of creating vigorous, uniform varieties of maize. Most candidates were able to describe the crossing of plants with desired characteristics; many of these needed to go on to express the idea of repeatedly selecting only the best of the offspring to breed from. Strong responses included the ideas of initial inbreeding to achieve uniformity and subsequent outbreeding to produce hybrid vigour.

(b) (i) Relatively few candidates were able to interpret the diagram to explain why IR8 was an improvement on PETA. Many candidates described 'better yield' or 'more edible grains' without expressing the idea of the grains constituting a greater proportion of the plant in IR8, with relatively less waste in stem and leaf growth.

(ii) Few candidates grasped the idea that the DNA of the rice was sequenced to identify or check for the two beneficial alleles.

(iii) Most candidates described the backcross of the rice variety as increasing yield or limiting inbreeding depression. Some candidates mentioned high yield and needed to add the idea of increasing the yield or maintaining a high yield for further credit.

(c) (i) A significant proportion of candidates described the effects of gibberellin on germination, which were irrelevant in this question on stem elongation. The strongest responses described how gibberellin caused cell elongation in variety **A**, including details of gibberellin binding to its receptor and DELLA protein being broken down to release the transcription factor PIF. Many answers identified that variety **B** did not respond to gibberellin treatment and a few of these suggested that variety **B** may lack a functional gibberellin receptor. Most candidates who mentioned the *Le* / *le* gene misinterpreted the information in the question and suggested that variety **A** had the dominant *Le* allele, whereas in fact variety **A** is homozygous for the recessive *le* allele.

(ii) Most candidates knew that transcription factors control gene expression. The majority also knew that they bind to a promoter to allow RNA polymerase to bind. Some candidates wrongly stated that the transcription factor was part of the DNA.

Question 7

(a) The genetics cross was a simple monohybrid cross concerning sex linkage in cats. Some candidates did not state what symbols they were using or gave symbols without identifying what they meant. Candidates should choose appropriate letters to represent the alleles and provide a key to show what they mean. Here the X chromosome should ideally have been included and as both ginger and black express in a heterozygous female, the letters for the alleles should have been two different capitals, e.g. B for black fur and G for ginger fur. Most candidates showed sex linkage in their cross; for the parental genotypes, a minority did not show the sex chromosomes (just BG and G–), or wrongly attached an allele to the Y chromosome of the male parent. Some answers needed to give the offspring phenotypes in the same order as the offspring genotypes to show how these are linked together to gain the credit.

(b) Many candidates showed a poor understanding of the *TYR* gene. Instead of stating that it coded for the enzyme tyrosinase, many stated it coded for the single amino acid tyrosine. Many candidates provided the names of the intermediates DOPA and dopaquinone and needed to explain that they are steps in a metabolic pathway for the synthesis of melanin from tyrosine. Suitable language to describe this is that tyrosine is converted into DOPA and DOPA is converted or changed into dopaquinone.

Question 8

(a) Candidates were almost universally successful in naming the parts of the kidney and nephron.

(b) Many candidates scored well on describing the graph showing how blood ADH concentration affects urine concentration and urine flow rate. A significant proportion of candidates could have improved by studying the key to establish which curve was which to make sure they used the correct *y*-axis scale to read off figures.

(c) Most candidates gave a partial account of the effect of ADH on the cells of the collecting duct. Details that were omitted in many responses included the location of the ADH receptor on the cell membrane of the collecting duct cells, the roles of G protein and cAMP, and the end result that more water is able to leave the nephron or enter the blood after aquaporins are added to the collecting duct cell membranes. Many candidates spent valuable time in writing about the control of ADH secretion in response to low water potential in the blood, which was not relevant to the question asked.

Question 9

(a) Weak responses often gained some credit by interpreting and comparing the two graphs, although many of these described differences in values without using the correct terminology to describe the events, e.g. resting potential and depolarisation. Some candidates suggested that the action potentials started on the left-hand side of the graph, during the resting potentials. Many candidates wrongly equated the term 'refractory period' with the correct alternatives of 'relative refractory period' or 'hyperpolarisation'.

(b) (i) A common misinterpretation was stating that Ca^{2+} ions would not be released in the latent phase, and therefore describing only the neuronal action potential, or describing how the binding sites on actin would not be exposed for myosin to bind. Few candidates described Ca^{2+} ions as diffusing, rather than just being released from, the sarcoplasmic reticulum. Some candidates wrongly suggested that power strokes would be happening in the latent phase, whereas this would cause the steep increase in muscle tension seen later in the contraction phase.

(ii) Very few candidates were able to understand and express the subtle reason for the gradual decrease in tension during the relaxation phase. Some candidates understood that the breaking of cross bridges would take time, and a very few expressed the idea that they would break at different times rather than all at once.

Question 10

All candidates were able to gain some credit on this exercise. The most accessible answers were the first word, internal, and the third, receptor. Candidates frequently correctly identified negative feedback as the process for the second space. Candidates had more difficulty with the fourth and fifth spaces. Instead of endocrine, some wrote 'secretory' and instead of glycogen, some wrote 'glucagon'.

BIOLOGY

Paper 9700/42
A Level Structured Questions

Key messages

1. Candidates are often asked to describe the data when presented with a graph or table. This is not always the case. In **Question 10(a)**, many candidates lost out on the credit available by describing the results of the graph instead of explaining them.
2. Some questions, such as **Question 4(c)**, ask for two answers. In this type of question only the first two responses will be marked and subsequent answers will be ignored, even if correct.

General comments

Some candidates scored highly in this paper and there were many candidates who scored in the lower part of the range. **Questions 4**, **6** and **8** proved to be the most challenging.

Comments on specific questions

Question 1

(a) The role of the IUCN was frequently confused with that of CITES, with many candidates commenting on the banning of hunting of the Asiatic lion or its protection in National Parks and zoos. Most responses showed understanding of the importance of the IUCN in identifying those species that are endangered or on the verge of extinction, and a small number of candidates mentioned their inclusion on the Red List. Many appreciated that education and the spreading of awareness of the plight of these species would be crucial to their survival.

(b) Most candidates understood that placing the old and weak cattle at the edge of the enclosures meant that they were the most likely to be predated, thereby sparing the younger, stronger cattle. Some incorrectly suggested that the cattle were to prevent the Asiatic lions from extinction by giving them enough to eat, or protect the Maldhari population, rather than other cattle.

(c) Several candidates confused IVF with artificial insemination and simply described the introduction of sperm into the female reproductive tract. Very few answers mentioned the administration of hormones to the lioness to induce superovulation and most understood that ova would be extracted from the female. Many candidates explained that the ova would be fertilised by sperm, or semen, in a Petri dish: the resultant zygote would then divide to form an embryo that could be implanted into the uterus of either the same animal or a surrogate of a similar species. Some responses could have improved by referring to ‘ova’ consistently rather than ‘eggs’. Weaker responses suggested that the zygote would be implanted or did not mention the uterus. Few references to the method of harvesting of the ova, such as the use of a needle, were seen. Some candidates misread the question and explained the advantages of IVF, as opposed to its method, including embryo screening and the use of surrogacy for multiple births to increase the size of the population.

Question 2

(a) (i) Many candidates provided full outlines of the process of respiration by yeast in anaerobic conditions. Some gave more detail of the process of glycolysis than was required by the command word ‘outline’. Other candidates missed out glycolysis completely and started with pyruvate.

There was some confusion as to the correct type of reaction. For instance, that pyruvate is converted to ethanal by decarboxylation and that ethanal is converted to ethanol by reduction.

Sometimes a candidate wrote that pyruvate was converted to ethanal by both decarboxylation and dehydrogenation as well, so was not given the credit. Others described lactic acid fermentation instead of the ethanol fermentation pathway required, as the question referred to yeast.

Many candidates correctly identified an enzyme linked to one of the reactions, most commonly ethanol dehydrogenase for the reduction of ethanal to ethanol. Few candidates correctly referred to NAD being regenerated during the ethanal reduction step.

(ii) Most candidates found this question challenging. Many responses stated that an advantage of anaerobic respiration was that the yeast could still respire and needed to go further to link this with the survival of the organism. The most often seen creditworthy point was the continued production of ATP, and some candidates gained credit for identifying that glycolysis would still be taking place due to the regeneration of NAD.

Some candidates discussed the advantage to humans in terms of bread and beer production rather than the advantage to the yeast.

(b) Most candidates gained credit for correctly identifying the difference in the trends; that the GM strain had a higher concentration of ethanol. The question asked for both GM and non-GM trends in ethanol production to be described. While candidates frequently identified ethanol production levelling off in the non-GM strain, they often needed to add that the GM strain also did this. Some described the trend of each line separately and needed to write comparatively to gain the credit.

Most candidates successfully provided a paired data quote with correct units. Some answers gave incorrect figures from the graph, often citing $2\,g\,dm^{-3}$ instead of $1\,g\,dm^{-3}$ for non-GM, caused by them misreading the ethanol axis scale.

Some candidates were confused by the graph and referenced starch rather than ethanol and a significant number attempted to explain the results rather than describe the trends by way of a comparison.

(c) Very few candidates gained credit here. The most common correct answer was that the enzymes worked at similar rates. Some answers showed understanding and missed out on the credit by using inaccurate language; writing the amount of starch hydrolysed was the same, or that the amount of glucose made available was the same, instead of the concentration of starch or glucose. Many candidates misunderstood the question and described the enzymes having a very high optimum temperature or that enzymes were added in the high temperature method.

(d) Most candidates described an increase in energy demand and needed to go on to link this idea to an increased need for fuel or electricity that would be expensive.

Credit was commonly achieved for identifying that the high temperature method required extra enzymes.

Question 3

(a) (i) Most candidates identified at least one of the structures correctly. It was quite common for full credit to be gained.

(ii) Most candidates were able to gain some credit for this question and a few achieved full credit. Candidates were asked for an explanation of how grana are adapted for their specific role in photosynthesis. The most successful answers were set out with a brief description of each feature, linked directly to its specific role. Several candidates listed many features and needed to go on to link them to their specific role to be awarded credit. For example, some identified the presence of the ETC without mentioning the transfer or release of energy therein. Similarly, ATP synthase was often missing the 'to produce ATP' part of the answer. ATP synthase was sometimes wrongly described as ATPase. Several candidates needed to use the name of the stacks or discs (thylakoids) and instead used the question wording 'grana'. Many of the weaker responses correctly described the presence of photosynthetic pigments to absorb light, and could have gone on to be credited if they had used the term 'absorb' rather than the incorrect 'trap' or 'capture'. The most able candidates recalled that the thylakoid membrane was impermeable to protons and that a proton gradient formed due to an accumulation of protons in the thylakoid space. The linking of stacked thylakoids to large surface area was commonly seen and a few went on to relate this to

maximising light absorption for further credit. Some needed to explain further and specify that the light absorbing pigments were photosynthetic. Few candidates described the OEC as a feature that carried out the photolysis of water.

There were many candidates who described the light dependent stage of photosynthesis and missed out on credit as they needed to link these to the adaptations.

(b) (i) Most candidates gained a good level of credit on this question by identifying that the pH increased in the light and decreased again in the dark. They also gave comparative figures from the graph to support. Many candidates were able to describe fluctuations in the data shown. Some higher-achieving answers noted that the increase in pH into light conditions was sharp and that the decrease in pH into dark conditions was gradual.

The weakest answers made no mention of the light conditions. The instruction to describe was sometimes not followed and candidates instead explained the results.

(ii) This was a challenging question and only the strongest respondents gained credit. Many candidates were able to make the link between pH, movement of hydrogen ions and the generation of ATP in chemiosmosis. The location of the ion movement (stroma to thylakoid space and back again) was often missing or mistaken and those who were able to identify that hydrogen ions were being pumped into the thylakoid space needed to clearly link this back to the pH of the stroma being higher. Similarly, candidates who mentioned ATP synthase often needed to state or imply the destination the hydrogen ions were passing back to. Some incorrectly referenced ATPase instead of ATP synthase. It was not uncommon to see mitochondrial features named in error. Some candidates needed to be more specific when naming the thylakoid space or lumen. Instead, they wrote that H^+ went into the thylakoid or thylakoid membrane rather than into the lumen. Others needed to reference the change in pH and incorrectly referenced acidity.

Question 4

(a) Most candidates were awarded some credit, and a small number achieved the maximum available. The most commonly seen correct answers related to the 'cutting and sticking' points on the use of restriction enzymes and ligase enzymes, followed closely by the insertion of the vector into a bacterium or host cell. Many could have mentioned that the bacteria would be cloned, or detailed the ultimate end point of the process with the expression of the new gene and the production of the clotting factor protein. Inaccurate language led to many candidates missing out on the credit available for reference to enzymes. Genes were described as 'cut' instead of being 'obtained' or 'cut out', and mRNA was referred to as being converted into cDNA instead of being used as a template. Detailed explanations involving sticky ends were common and not necessary for an outline of the procedure.

Most candidates needed to use the relevant learning outcome to state the principle of genetic engineering as the manipulation of DNA to modify an organism's characteristics.

(b) (i) Generally, candidates were much more likely to gain credit from the first part of the question (assess which form of haemophilia should be treated first) than the second (whether haemophilia should be treated with gene therapy at all). Most candidates either identified that haemophilia A was more common or that Haemophilia B's gene size was preferable as it would fit into the virus vector. Many candidates could have stated both of these points, rather than just one, for further credit. The most common creditworthy justification for attempting gene therapy was that it cured people. More commonly, candidates decided gene therapy should not be attempted due to side effects, like the risk of cancer.

(ii) Most candidates gained some credit for this question for identifying that promoters are integral to gene expression, with many gaining full credit for the added detail that they are the site of RNA polymerase or transcription factor binding.

Few candidates explained that a promoter would allow the gene expression to occur at the right time or in the right quantities and in the right tissue.

(iii) Most candidates understood that the virus would be destroyed by the immune response. They often stopped short of explaining that the gene would therefore not be delivered to the target cells.

Some candidates also explained that host cells that had already taken up the virus would also be destroyed.

(c) Candidates found this question challenging. Stronger responses gave at least one advantage of gene editing in the treatment of haemophilia. Some identified that it was a more precise treatment and carried fewer risks than adding a functional gene via a virus vector, as no immune response would occur or cancer due to the gene being inserted in the wrong place.

Many candidates gave a general statement on gene editing and needed to state that the patient's own gene would be used. Very few realised that not having to insert a gene or allele would be a distinct advantage and even fewer made the link that a promoter would no longer be needed.

Question 5

(a) There were some very detailed descriptions of the stages taking place in the polymerase chain reaction. Most candidates stated that at 95 °C the hydrogen bonds between the DNA strands would break, denaturing the DNA and causing the two strands to separate. Stronger candidates also understood that the primers would anneal at 50 °C, and that raising the temperature to 72 °C would allow *Taq* polymerase to synthesise a complementary strand using the original DNA as a template. Weaker responses simply commented that the primers would be added to the DNA, omitting that they would bind, or that *Taq* polymerase would cause strand elongation without mentioning the synthesis of a completely new strand.

(b) Accounts of the differences in the data sequences of the three different species of *Myosotis* needed to include further details and few candidates achieved full credit for this section. Stronger responses appreciated that in *M. pygmaea*, and similarly *M. pulvinaris*, different populations of the same species would be geographically isolated, preventing any gene flow between them. Others referred to the sea or the mountains as geographical barriers to interbreeding. Some also stated that the different populations of the two alpine species would have different mutations, although few mentioned the subsequent change in gene pools or different changes in allele frequencies. Credit was most frequently awarded for recognising that the respective populations of *M. pygmaea* and *M. pulvinaris* would be subjected to different selection pressures or environmental conditions, while for *M. pottsiana* they would be the same or similar. Some candidates also commented that interbreeding would be possible between the populations of *M. pottsiana* in the absence of geographical isolation. Some believed that speciation had already taken place, either allopatric in populations of *M. pygmaea*, or sympatric in populations of *M. pulvinaris*.

Weaker candidates struggled to interpret the information they had been given and many needed to address each species separately, making broad, and therefore inaccurate, statements about all three. Credit was also lost for confusing the terms 'species' and 'populations'.

(c) The majority of candidates were able to suggest at least one factor that could drive genetic changes in populations of *Myosotis*, most notably, genetic drift (or suitable alternatives) followed by mutation. Migration and selective breeding were less frequently seen.

Question 6

(a) (i) Many candidates were able to state the structural differences between the *lac* operon and the *trp* operon regarding the number of genes and the presence of an attenuator. They generally found making a comparison of the differences in structure was much easier than commenting correctly on the differences in control. Common mistakes were candidates using the word 'substrate' instead of naming lactose and tryptophan or describing one of the operons without making a comparison.

(ii) The most able candidates correctly answered that there was only one promoter and a few of these responses explained that all the products worked together. They often stated that genes, or simply 'they', work together in some way.

(iii) Many candidates gave the correct answer for structural genes, although a common incorrect answer was that structural genes code for proteins which work inside cells. For regulatory genes, many incorrectly stated that the regulatory genes, rather than their products, controlled gene expression.

(iv) Candidates found this question difficult, and many referred to the enzyme rather than to tryptophan itself. Very few mentioned end-product inhibition or negative feedback.

(b) (i) This question was generally well answered by most candidates. The most common errors were to state that gibberellin breaks down DELLA or that the gene expressed was coding for amylase. Some mistakenly wrote about the role of enzymes in germination, which was not required.

(ii) Most candidates correctly stated transcription factor.

Question 7

(a) Most candidates were able to give clear definitions of dominant and recessive alleles. Many stated that a dominant allele always has an effect on the phenotype and that the recessive allele only has an effect on the phenotype if the dominant allele is absent.

(b) Many candidates found this sex-linked cross question difficult. Candidates often omitted the sex chromosome **Z** when writing their symbols key at the start. Some candidates needed to write the allele symbols **B**/**b** as superscripts, and some missed them out altogether. A common mistake was to add a symbol to the **W** chromosome.

(c) This question was well attempted with many candidates getting full credit. The most common mistake was to cross the bronze male with a homozygous recessive female rather than a brown female. Some candidates were confused and crossed two male turkeys together.

Question 8

(a) Some candidates made no attempt to answer this question, which involved putting two labels on a diagram. Many answers were imprecise. Credit was lost if the label line either did not touch the membrane or went through it.

(b) This question asked candidates to explain how the cells of the proximal convoluted tubule are adapted for selective reabsorption. Many responses needed to mention the specific features of these cells and their use in the process of selective reabsorption. Consequently, mitochondria were mentioned but not large numbers of them. Similarly, quantities of cotransporters were rarely stated, although credit was given to a clear comment of their function. Few candidates were able to use the diagram provided to help them to achieve full credit in this question.

(c) Few candidates were able to divide 2.00 by 0.03 and then round up to achieve the answer of 67. Many candidates needed to follow the command to write their answer to the nearest whole number for further credit, having correctly completed the calculation.

Question 9

(a) Most candidates were able to gain some credit for matching the numbers for the state of the voltage-gated channels with the appropriate description. The most common error was to misidentify the period of hyperpolarisation as **2** instead of **3**. Weaker responses included the section of the action potential instead of the number.

(b) The functions of the myelin sheath were generally well understood, with many candidates easily achieving full credit. Many responses began by stating that the myelin sheath was an insulator, preventing the movement of ions so that depolarisation can only take place at the nodes of Ranvier, resulting in the impulse, or action potential, jumping from node to node. Many went on to mention that saltatory conduction would increase the speed of transmission of the action potential, although references to a faster action potential were not credited. Fewer candidates mentioned that the myelin sheath was composed of Schwann cells or that there would be longer local circuits between the nodes.

Question 10

(a) Several candidates misread the question and simply described the graph rather than explaining the relationship between blood glucose concentration and blood glucagon concentration. Stronger candidates stated that blood glucagon concentration increased as a result of decreasing blood glucose concentration, often continuing to describe the mechanism of action of this hormone in the

stimulation of glycogenolysis and gluconeogenesis in liver cells and subsequent release of glucose into the bloodstream to elevate its concentration. Some stronger answers went on to provide detail of glucagon secretion by the alpha cells of the Islets of Langerhans. Weaker candidates suggested that the breakdown of glucagon itself would increase the blood glucose concentration. Few candidates mentioned that the process was a negative feedback mechanism.

(b) Almost every candidate understood that glucagon would bind to its receptors because of its complementary shape and many appreciated that this would lead to the activation of a G-protein, although some referred to an enzyme cascade or second messenger. Few correctly identified the enzyme that would be stimulated by the G-protein as adenylyl cyclase. A common error was to suggest that glycogen phosphorylase would be activated.

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Paper 9700/43
A Level Structured Questions

Key messages

Candidates should make sure that they read each question carefully. To be successful candidates need to be able to interpret the question material, apply skills and recall learnt facts. Some of the skills tested in this paper were suggesting explanations in novel contexts (**Question 1** and **Question 3**), constructing reasoned explanations based on facts (**Question 2**, **Question 4** and **Question 5**), interpreting pictorial information (**Question 6**) and describing graphs (**Question 8** and **Question 9**).

General comments

Candidates should take time in the exam to check through answers to help avoid losing credit by contradicting themselves or writing ambiguously.

Comments on specific questions

Question 1

This question concerned the conservation of the wild Bactrian camel.

(a) Suggesting reasons why the wild Bactrian camel has become endangered was well attempted and many candidates scored full credit. As the species has become endangered (i.e. a change has occurred), candidates should have been thinking about what has changed in their environment to cause this, with changes likely to be linked to human activity. Habitat loss and competition with introduced domestic livestock are the major factors for this species. Candidates did not achieve credit for listing ecological principles, such as competition, predators and the ratio of births to deaths, without considering how these factors have changed as a result of human activity.

(b) While some candidates had a clear understanding of the role of the IUCN in nature conservation, many confused this supranational data collating agency with CITES, WWF and other organisations that play a more active role in habitat management and species conservation. Many candidates correctly described the role of the IUCN in assessing, listing and categorising endangered species; relatively few referred to the Red List of Threatened Species.

(c) In describing the process of embryo transfer, many candidates misused terminology. As well as confusing processes such as *in vitro* fertilisation and artificial insemination, some candidates confused the pairs of terms: ovum and embryo, zygote and embryo, uterus and ovary. Many candidates correctly referred to the idea of surrogacy with the wild Bactrian camel providing the embryo which would then be carried to full term by the less endangered dromedary camel. The practical details of carrying this out were less well described, with few responses mentioning screening embryos and freezing them for later use.

Question 2

(a) Most candidates could name a chloroplast pigment, although some wrote ‘chlorophyll alpha’ or ‘chloroplast a’ instead of chlorophyll *a*.

(b) Candidates struggled to explain what an absorption spectrum and an action spectrum show, although many were able to express the idea that the curves match or show the same pattern. While candidates frequently wrote about wavelengths of light, few realised that the absorption

spectrum shows how much of each wavelength is absorbed by a pigment, or that the action spectrum plots the rate of photosynthesis against the wavelengths in the spectrum of visible light.

(c) This was generally a well-answered question. Candidates needed to refer to the enzyme-controlled elements of photosynthesis and to explain how temperature increase would affect these reactions. Reference to kinetic energy and the formation of enzyme-substrate complexes helped to secure credit for some candidates. Some responses referred to the effect of temperature on the opening of the stomata rather than the direct effect on the reactions of photosynthesis.

(d) This was a straightforward question which was well answered in most cases. Candidates outlined the carboxylation and reduction steps of the Calvin cycle and linked triose phosphate to glucose or starch, and a few mentioned how glucose is polymerised to form the starch polymer from glucose monomers. Errors included stating that the three-carbon entity GP 'breaks down' to the similarly-sized entity TP and stating that reduced NAD rather than reduced NADPH was used along with ATP in this step.

Question 3

(a) (i) Candidates were asked to suggest and explain why the inner mitochondrial membrane remains intact when the organelle is placed in pure water. Candidates needed to describe a property of the inner mitochondrial membrane and link this to an explanation, generally involving the degree to which osmosis would occur. The most common correct suggestion was that the inner membrane is impermeable to water so water could not enter the matrix by osmosis. Some candidates mentioned that the inner membrane was folded, and a few went on to explain that this would allow the inner membrane to expand when the volume of the matrix expanded.

(ii) Successful responses described the roles of molecules like pyruvate, oxaloacetate, citrate and oxygen. Most candidates were unable to name three molecules that are in the matrix and are not coenzymes. Common incorrect suggestions were the coenzymes NAD, FAD, ATP and coenzyme A. Other incorrect suggestions were ions (e.g. H^+), organelles (e.g. ribosomes) and molecules that are situated on the inner mitochondrial membrane and not in the matrix (e.g. ATP synthase).

(iii) Candidates generally realised that cardiolipin prevents ion movement across the inner mitochondrial membrane and needed to go on to specify that it is hydrogen ions that must not be allowed to diffuse across, to maintain the proton gradient.

(b) (i) Candidates showed good recall and understanding of the events that establish a membrane potential across the inner mitochondrial membrane. Some candidates confused hydrogen ions with hydrogen atoms, and some confused the role of the H^+ ions with the role of the electrons. Most correctly stated that electrons pass down the electron transport chain and that this releases energy to pump the protons into the intermembrane space. Occasionally a candidate stated that the H^+ were pumped in the wrong direction into the matrix. Some answers finished early without relating the accumulation of protons to the establishment of the proton gradient, while others continued beyond the establishment of the gradient and described its use in driving ATP synthesis. A few candidates made the mistake of writing 'inner membrane space' rather than 'inter-membrane space'. Occasionally an answer referred to protons building up 'inside the inner membrane', implying within the phospholipid bilayer.

(ii) The majority of candidates were able to describe phosphate ions as moving via facilitated diffusion or through a carrier protein. Many were also able to link the movement of P_i with that of protons diffusing into the matrix.

(iii) Candidates found this question very hard to answer and very few scored credit. The idea of linking ADP and ATP transport mostly drew comments about efficiency of energy use rather than ensuring a constant supply of ADP so that ATP could continue to be made in the required amounts. Strong responses discussed the idea of ATP production being regulated.

Question 4

This question led the candidate through a sequence of developments in genetic manipulation, from the initial application of genetic engineering in making a recombinant protein in bacteria, to gene therapy in humans,

and then to the newer technique of gene editing. Many candidates could have improved their responses by distinguishing more carefully between these different landmark techniques.

(a) Answers often showed an incomplete or confused understanding of the main principles of genetic engineering. The context of the question was the use of recombinant DNA to produce a therapeutic protein. This context was often overlooked by candidates who focused on gene therapy of a human patient. The aspects of genetic engineering that were best known by candidates were the names and roles of the enzymes: restriction endonuclease, reverse transcriptase and DNA ligase. Less understood aspects were the separate stages involved in creating a recombinant plasmid and then inserting this recombinant vector into a new host cell, and also the need for transformed cells to show the expression of marker genes and for cloning the introduced gene.

(b) (i) Most answers referred to mitosis or cell division in multiplying the number of stem cells, and some went on to clearly describe the inheritance of the functional gene by the resulting daughter cells.

(ii) A large majority of candidates were able to explain that the purpose of a promoter is to allow gene expression by acting as the binding site for RNA polymerase or transcription factors. A small number confused RNA polymerase with DNA polymerase.

(iii) Candidates who gave very general answers, such as that the virus may cause side effects, did not gain credit. Stronger answers suggested that the virus could potentially cause immune responses or infectious diseases. Some candidates understood that random insertion of retrovirus DNA in the host cell genome might disrupt the expression of other genes. The overarching ethical issue being that a medical treatment should do less harm than good.

(c) Many candidates knew that Huntington's disease is caused by a dominant allele. Most candidates were familiar with the idea of gene editing. Answers were sometimes too general and did not apply to this particular example. Responses suggested that gene editing enabled the removal of the faulty allele, and many went on to state that this would be replaced with a normal allele. Relatively few responses explained that Huntington's disease is caused by extra repeats of the triplet CAG and that these extra repeats needed to be removed. The strongest answers explained that adding a normal recessive allele in this case would not work since the dominant allele is still present and being expressed.

Question 5

(a) This question required careful thought about the alpine habitat and an understanding of the question context. In this example there was no straightforward geographical isolation between two populations – candidates were told that the nearest islands were over 1500 km away to show that the new species originated on the South Island. Good responses described how plant species that initially grew at lower altitudes, adapted to higher ground through mutation and natural selection, forming new specialist alpine species. Candidates that demonstrated appreciation of the particular demands of the alpine mountain habitat, such as colder temperatures, thinner soil and strong winds, were more likely to gain credit in describing how mutation could aid plant survival and adaptation.

Despite the question stating that the alpine habitat is an area where trees cannot grow, many candidates referred to the alpine plants as trees. Candidates may not have noticed that the question referred to a large number of (different) alpine plant species, each one descended from a different starting lowland plant species in New Zealand. Some answers implied a large population of a single plant species (i.e. a large number of plants) developing due to lack of competition and herbivores in the mountains. Referring to different selection pressures causing mutation, lost some candidates credit. Candidates who relied on simple recall of past mark schemes about allopatric speciation did not achieve credit.

(b) (i) **Fig. 5.1** proved to be difficult for candidates to interpret correctly. The question was based on the idea that alpine plant species can only begin to develop when the mountains are higher than the treeline. Correct interpretation of **Fig. 5.1** showed that the mountains were consistently higher than the treeline from approximately 1 million years ago, and many candidates focused on the information that the current treeline is 1200 m and used this to give a wrong time figure from the graph.

(ii) Most candidates scored credit by writing that the DNA of the alpine species would need to be compared with some other DNA. A few realised that the correct comparison would be with the DNA of related lowland species. For example, a plant species in the same genus that grows at lower altitudes. Many responses suggested comparing with plants from millions of years ago which is not feasible. Some candidates suggested that similarities and differences in the DNA sequence should be counted and needed to go on to make clear the idea that the number of differences (mutations) relates to time due to the constant mutation rate (molecular clock idea).

Question 6

(a) Many candidates described points relating to artificial selection in general without focusing on the specific example of creating vigorous, uniform varieties of maize. Most candidates were able to describe the crossing of plants with desired characteristics; many of these needed to go on to express the idea of repeatedly selecting only the best of the offspring to breed from. Strong responses included the ideas of initial inbreeding to achieve uniformity and subsequent outbreeding to produce hybrid vigour.

(b) (i) Relatively few candidates were able to interpret the diagram to explain why IR8 was an improvement on PETA. Many candidates described 'better yield' or 'more edible grains' without expressing the idea of the grains constituting a greater proportion of the plant in IR8, with relatively less waste in stem and leaf growth.

(ii) Few candidates grasped the idea that the DNA of the rice was sequenced to identify or check for the two beneficial alleles.

(iii) Most candidates described the backcross of the rice variety as increasing yield or limiting inbreeding depression. Some candidates mentioned high yield and needed to add the idea of increasing the yield or maintaining a high yield for further credit.

(c) (i) A significant proportion of candidates described the effects of gibberellin on germination, which were irrelevant in this question on stem elongation. The strongest responses described how gibberellin caused cell elongation in variety **A**, including details of gibberellin binding to its receptor and DELLA protein being broken down to release the transcription factor PIF. Many answers identified that variety **B** did not respond to gibberellin treatment and a few of these suggested that variety **B** may lack a functional gibberellin receptor. Most candidates who mentioned the *Le* / *le* gene misinterpreted the information in the question and suggested that variety **A** had the dominant *Le* allele, whereas in fact variety **A** is homozygous for the recessive *le* allele.

(ii) Most candidates knew that transcription factors control gene expression. The majority also knew that they bind to a promoter to allow RNA polymerase to bind. Some candidates wrongly stated that the transcription factor was part of the DNA.

Question 7

(a) The genetics cross was a simple monohybrid cross concerning sex linkage in cats. Some candidates did not state what symbols they were using or gave symbols without identifying what they meant. Candidates should choose appropriate letters to represent the alleles and provide a key to show what they mean. Here the X chromosome should ideally have been included and as both ginger and black express in a heterozygous female, the letters for the alleles should have been two different capitals, e.g. B for black fur and G for ginger fur. Most candidates showed sex linkage in their cross; for the parental genotypes, a minority did not show the sex chromosomes (just BG and G–), or wrongly attached an allele to the Y chromosome of the male parent. Some answers needed to give the offspring phenotypes in the same order as the offspring genotypes to show how these are linked together to gain the credit.

(b) Many candidates showed a poor understanding of the *TYR* gene. Instead of stating that it coded for the enzyme tyrosinase, many stated it coded for the single amino acid tyrosine. Many candidates provided the names of the intermediates DOPA and dopaquinone and needed to explain that they are steps in a metabolic pathway for the synthesis of melanin from tyrosine. Suitable language to describe this is that tyrosine is converted into DOPA and DOPA is converted or changed into dopaquinone.

Question 8

(a) Candidates were almost universally successful in naming the parts of the kidney and nephron.

(b) Many candidates scored well on describing the graph showing how blood ADH concentration affects urine concentration and urine flow rate. A significant proportion of candidates could have improved by studying the key to establish which curve was which to make sure they used the correct *y*-axis scale to read off figures.

(c) Most candidates gave a partial account of the effect of ADH on the cells of the collecting duct. Details that were omitted in many responses included the location of the ADH receptor on the cell membrane of the collecting duct cells, the roles of G protein and cAMP, and the end result that more water is able to leave the nephron or enter the blood after aquaporins are added to the collecting duct cell membranes. Many candidates spent valuable time in writing about the control of ADH secretion in response to low water potential in the blood, which was not relevant to the question asked.

Question 9

(a) Weak responses often gained some credit by interpreting and comparing the two graphs, although many of these described differences in values without using the correct terminology to describe the events, e.g. resting potential and depolarisation. Some candidates suggested that the action potentials started on the left-hand side of the graph, during the resting potentials. Many candidates wrongly equated the term 'refractory period' with the correct alternatives of 'relative refractory period' or 'hyperpolarisation'.

(b) (i) A common misinterpretation was stating that Ca^{2+} ions would not be released in the latent phase, and therefore describing only the neuronal action potential, or describing how the binding sites on actin would not be exposed for myosin to bind. Few candidates described Ca^{2+} ions as diffusing, rather than just being released from, the sarcoplasmic reticulum. Some candidates wrongly suggested that power strokes would be happening in the latent phase, whereas this would cause the steep increase in muscle tension seen later in the contraction phase.

(ii) Very few candidates were able to understand and express the subtle reason for the gradual decrease in tension during the relaxation phase. Some candidates understood that the breaking of cross bridges would take time, and a very few expressed the idea that they would break at different times rather than all at once.

Question 10

All candidates were able to gain some credit on this exercise. The most accessible answers were the first word, internal, and the third, receptor. Candidates frequently correctly identified negative feedback as the process for the second space. Candidates had more difficulty with the fourth and fifth spaces. Instead of endocrine, some wrote 'secretory' and instead of glycogen, some wrote 'glucagon'.

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Key messages

Candidates should read all parts of the question carefully, including the background information provided that introduces each investigation. Candidates should be prepared to evaluate unfamiliar scientific methods together with analysing and evaluating data in complex graphs and tables. To access the highest grades, sound knowledge needs to be accompanied by application in suggesting conclusions. When planning an investigation, it is important to set out the work in a logical way and for it to be detailed enough for another person to follow. When planning such investigations, candidates should read the instructions carefully, especially when asked to not repeat details from previous questions, as no credit will be awarded for this.

General comments

The responses covered the whole mark range for the paper. Candidates were challenged most with providing a description of how to prepare dilutions in **Question 1(d),** with explaining why the statement provided was not supported in **Question 2(b)(i)** and whether the information given was or was not supported in **Question 2(b)(ii)**.

Comments on specific questions

Question 1

The theme in this question was investigating the effect of two antibacterial substances on the bacterium *Bacillus subtilis*.

(a) (i) This was answered correctly by many candidates. Some responses only stated that the cotton wool would allow oxygen to enter the flask. A complete answer that also mentioned respiration was required to gain credit.

A few candidates stated that the cotton wool would allow gases such as carbon dioxide to escape or trap bacteria and these did not gain credit.

(ii) Correct answers explained that increased bacterial growth would cause the turbidity of the broth culture to also increase. Simply stating that bacteria cause turbidity was not sufficient. Some candidates suggested a suitable method to measure turbidity, such as the use of a colorimeter or a colour chart. These answers were also creditworthy.

A few responses suggested that carbon dioxide (from the respiration of bacteria) caused the cloudiness observed. This is incorrect as no limewater was present in the culture tubes.

(b) The investigation was looking to identify the lowest concentration of antibiotic solution that appeared to kill or inhibit the growth of *B. subtilis*. Therefore, the correct control should allow a comparison to be made between the culture tubes containing antibiotic and a control tube where no antibiotic has been used. Candidates who replaced the antibiotic solution with either distilled water or nutrient solution therefore gained credit.

Candidates often incorrectly referred to standardised variables such as temperature or the volume of broth culture used. Use of the specification term ‘standardised variables’ rather than ‘control variables’ should help to avoid this misunderstanding.

(c) Several candidates suggested that the enzymes catalase or peroxidase could be used to remove hydrogen peroxide. The use of an inorganic catalyst such as manganese oxide was also acceptable to gain credit.

Candidates often struggled to explain why removing hydrogen peroxide would make the results more valid. A clear statement that the results gained would be due only to MGO or not due to hydrogen peroxide was required.

(d) A 10% solution of honey is made by diluting the 100% stock solution with nutrient solution in the ratio 1:9; for example, by diluting 1 cm^3 of stock solution with 9 cm^3 nutrient solution. Correct volume units should always be given.

The question rubric asked candidates to 'Construct a table to show how the dilution is made for the 10% solution and the other concentrations that the candidate could use'. To gain credit, a table had to be drawn with information for at least 5 dilutions including the 10% solution of honey. A diagram showing the procedure for dilution was not sufficient. The volumes of both 100% stock solution and nutrient solution required to make each concentration should be included in the table.

Those candidates who chose a serial dilution method often had problems in making their tabulated volumes in the table correct.

(e) This was answered correctly by the majority of candidates. As the dependent variable should be the variable that is measured, 'bacterial growth/population size' did not gain credit. It was the turbidity of the broth culture that is measured in this investigation, so this was the correct dependent variable.

(f) Most candidates were able to explain that the MGO in Manuka honey would be able to kill or inhibit the growth of *B. subtilis*. Candidates were often unable to word their prediction in such a way as to gain credit. The prediction should clearly link the higher concentrations of Manuka honey to decreased turbidity of the culture tubes. References to lower bacterial growth alone were not sufficient.

(g) Many candidates were familiar with this style of question and were able to give well-planned responses incorporating all the main elements of a biological investigation. Some candidates found this particular investigation challenging due to its unfamiliarity.

Several candidates gained credit by suggesting that the volume of broth culture and the volume of Manuka honey should be standardised. Only a few candidates remembered that the broth culture should be mixed with the Manuka honey at the start of the investigation.

Credit was given for the use of a water bath or incubator to standardise the temperature. The time of incubation also needed to be standardised as this needed to be long enough to allow bacterial growth to occur. Incubation times of less than 24 hours would be insufficient. A few candidates correctly suggested that buffer could be used to standardise the pH of the culture tubes.

Many candidates were unsure how to measure the dependent variable. Simply measuring or observing the turbidity of the broth culture was insufficient. Credit was most often given to those candidates who used a colorimeter to measure the turbidity, although using a colour chart or checking the visibility of a cross in the background were also accepted. The question asked candidates to determine the lowest concentration of Manuka honey solution that would kill or inhibit the growth of *B. subtilis*. Therefore, noting the concentrations at which the broth culture was clear would allow this lowest concentration to be determined. Many candidates suggested repeating the procedure at least twice and calculating a mean. The term 'mean' should be used in a scientific context and candidates are advised to avoid using the term 'average'.

A risk assessment was required and was attempted successfully by several candidates. Risk assessments should be given in terms of the hazard, the risk associated with that hazard and the appropriate mitigation. For example, broth culture may cause irritation, so gloves should be worn.

(h) (i) Candidates often struggled to write a correct null hypothesis for this investigation. The key point of this investigation was to compare Manuka honey with Germania honey. Therefore, the null hypothesis should state that 'there is no difference in the effectiveness of Manuka honey and Germania honey'. The null hypothesis should not include reference to the concentration of honey.

As the statistical test used was χ^2, null hypotheses that referred to 'no relationship' or 'no correlation' were incorrect. A few candidates gave the alternative hypothesis rather than the null hypothesis.

(ii) Most candidates correctly recognised that the χ^2 values for concentrations 2 and 3 were significant, whilst the χ^2 value for concentration 4 was not significant.

(iii) Several candidates stated correctly that Manuka honey was more effective than Germania honey. To be given full credit for this question, candidates also needed to refer to the statistical analysis regarding the significance of the χ^2 tests. **Table 1.1** indicated that higher concentrations of Manuka and Germania honey showed a significant difference between the number of cultures with bacterial growth. Candidates who noticed this gained credit only if they clearly stated that the significant difference was shown by concentrations 1, 2 and 3. Alternatively, credit was awarded to candidates who noted that there was not a significant difference for concentrations 4 and 5.

Question 2

This question introduced candidates to an unfamiliar investigation on the effect of different diets on lactating Holstein cows.

(a) Many candidates realised that the cottonseed-free diet would allow a valid comparison to be made between the different groups of cows. Candidates needed to then extend their answers to include an explanation of why this cottonseed-free diet would be important. Standardising the diet of the cows or removing gossypol from the cows before the start of the investigation were sufficient to gain credit.

(b) (i) This question asked why the statement made by the candidate was not supported by the data. Therefore, correct answers needed to focus on the data from **Table 2.1**, and not on the overall design of the investigation. Candidates who discussed the dry matter intake of the cows, the small sample size or the age of the cows did not gain credit.

Several candidates noted that the standard error for each group's milk yield overlapped. Some then realised that this overlap in standard error indicated that the milk yields of groups **A**, **B**, **C** and **D** were therefore not significantly different. Few candidates gained credit by stating that the milk yields of different groups were similar. The lack of a statistical test was correctly suggested by some candidates.

(ii) Many candidates noticed the trend that as gossypol in diet increases, the milk yield of the cows also increases, and were therefore able to find evidence to support the candidate's statement. A clear trend was required to gain credit, rather than simply comparing two groups of cows. Several candidates also gave a paired data quote to illustrate this trend, and therefore gained further credit.

Fewer candidates were able to find suitable evidence to not support the candidate's statement. The idea that correlation does not mean causation and the lack of a statistical test were common correct suggestions. The lack of information about the nutritional content of the various diets, or criticism of diet **A** as a suitable control were rarely suggested.

(c) (i) This question was answered correctly by the majority of candidates. A few did not gain credit as they stated that a correlation was present and needed to clarify that the correlation was positive. Additionally, the statement 'as plasma gossypol concentration increases, free gossypol intake also increases' gained no credit as it is the free gossypol that causes plasma gossypol to increase.

(ii) Several candidates stated that diet **E** had the highest risk of gossypol toxicity. References to diet **E** having a higher risk or to several diets being of high risk were not specific enough to be creditworthy. Credit was given for ranking the diets in order of their toxicity from highest to lowest: **E**, **B**, **D**, **C**.

Those candidates who linked the toxicity of different diets to the cow's intake of both free gossypol and (–) isomer gained further credit.

There were many candidates who focused only on the toxicity of the (–) isomer. A paired data quote from **Table 2.2** for either free gossypol or (–) isomer intake allowed candidates to gain further credit.

Some candidates were credited for noting that free gossypol is easily absorbed and is therefore more toxic than bound gossypol. A few candidates suggested that toxicity was linked to the bound gossypol and careful reading of the information given at the start of **Question 2** was necessary to avoid this error.

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Key messages

- Candidates should read the whole of each question prior to answering.
- Certain themes commonly appear in these question papers such as preparing different concentrations of solutions by dilution, planning an investigation and statistical analysis of data. It is advantageous for candidates to have practised these skills as much as possible throughout their course.
- When planning an investigation, it is important to set out the work in a logical way and for it to be detailed enough to allow another person to follow it.
- Candidates should read the instructions carefully, especially when asked to not repeat details from previous questions, as no credit will be awarded for this.

General comments

Candidates were able to identify which statistical test was appropriate and explain why with ease. Weaker candidates were challenged when providing a description of how to prepare dilutions in **Question 1(b)(i)**, and when asked to make reference to results shown in tables for their answers to **Question 2(c)(iii)**, **Question 2(e)(ii)** and **Question 2(e)(iii)**. Many candidates did not do this and so did not gain credit.

Comments on specific questions

Question 1

(a) Candidates were asked to outline how a colorimeter is set up. Those who described that the colorimeter needed calibrating prior to measuring the intensity of the coloured solution gained credit. There were a variety of ways in which candidates could state this, with many correct answers including details about setting the colorimeter to zero by first inserting a cuvette filled with distilled water. The strongest answers also included details about using a coloured filter in the colorimeter, with a few candidates correctly making reference to the correct colour of filter. This needed to be a colour opposite purple on the colour wheel, in this case orange, yellow and green were all colours which gained credit.

(b) (i) This question asked candidates to describe how they would prepare a 0.1% solution of protein from a 1% stock solution and how they would prepare other concentrations which would allow a calibration curve to be produced. They were asked to construct a table and were provided with space in which to draw this. Many candidates were able to correctly provide information about how to prepare the 0.1% solution of protein.

Most answers included a table, with only a small number not doing so. Candidates should practise this skill to ensure that they add detailed column headings with units included. Without units, it was not always clear if candidates were referring to volumes of solution to be used or the concentrations they were preparing, and as such, these responses could not gain credit.

Many candidates were able to correctly include at least 5 different concentrations within the range of 0.1 to 1.0% w/v in their table. Some responses incorrectly included concentrations outside this range and did not gain credit for these.

(ii) Many candidates correctly identified the independent variable for preparing the calibration curve as the concentration of protein. References to the egg albumen were incorrect as this was not used to make the protein concentrations used to prepare the calibration curve. Those candidates who

recalled that the dependent variable is the factor that is measured directly during an experiment gained credit for referring to the absorbance or intensity of the purple colour being measured.

(iii) Many candidates were able to correctly place protein concentration on the *x*-axis and absorbance on the *y*-axis. Candidates should use the information provided in the question when faced with labelling axes. Almost all responses correctly gave the unit for protein concentration (%), and therefore were able to attain full credit. Most candidates were able to sketch a graph to show the expected result.

(iv) Candidates were asked to explain why different proteins of the same concentration will result in the same intensity of purple colour in the biuret test. Those candidates who referred back to information provided in the stem of the question, outlining that copper(II) ions (Cu^{2+}) in the biuret reagent bind with the nitrogen atoms that form the peptide bonds, gained credit. Further credit was awarded to those who correctly identified that this meant that the different proteins would have the same number of peptide bonds. Answers which stated that different proteins had the same number of nitrogen atoms did not gain credit, as it was not clear that they were referring to the nitrogen atoms in the peptide bond, as additional nitrogen atoms may be present in the R groups of individual amino acids.

(c) There were many clear and detailed plans which gained full credit. Less creditworthy responses tended to just copy out the basic procedure provided in the question. There were several candidates who spent time repeating how to use the colorimeter or how the standard protein solutions would be prepared. As stated in the question, this was not required, and therefore credit was not awarded for these details.

Many candidates were able to either state that the volumes of protein solutions and biuret solution would be standardised or suggested an actual volume to be used. Those candidates who referred to adding about 2 cm^3 did not gain credit. It needed to be clear that the same volumes would be added each time. Candidates also needed to use the term volume, rather than amount, to gain credit here.

Most candidates included what they would measure in their plans, with some correctly suggesting that they would measure either the absorbance or intensity of the purple colour. A few candidates did not gain credit as they referred to measuring the intensity alone without referring to the intensity of colour.

Since the question was about how to determine the concentration of protein in the egg albumen, many candidates realised that they also needed to measure the absorbance of the egg albumen. Successful answers included details about using the calibration curve of known protein concentrations to find the unknown protein concentration, with a small number of candidates also referring to the fact that the egg albumen needed diluting by a factor of 10 prior to testing.

Many candidates referred to the use of a water-bath and buffer in their answers, which were not relevant for this investigation.

Many responses mentioned replicating the test a suitable number of times, and this was sometimes linked to calculating an average. It is important to use the term ‘mean’ in scientific work and candidates should use this terminology as a matter of course. There were several candidates who were not clear that they would replicate each concentration at least three times and then calculate a mean for each concentration. Answers stating that they would repeat the whole experiment three times and calculate a mean, therefore, did not gain credit.

Safety issues should be specific to the investigation. Many candidates gained credit for correctly identifying a hazard, a risk and a suitable precaution. A few responses just referred to being careful when handling the biuret solution, protein solution or egg albumen, and this was insufficient to gain credit.

Question 2

(a) Candidates were asked to describe two features of an appropriate control group when investigating the increased urea concentrations in sheep. There were a variety of answers seen; amongst the

most common to gain credit was that the sheep needed to be the same age or that the same number of each sex of sheep was needed.

(b) This question asked why using RNA sequencing rather than DNA sequencing was more appropriate when identifying genes of interest, which in this case were the genes involved in urea metabolism or in urea transport out of cells. Successful answers referred to the fact that DNA sequencing would only identify the presence of the genes and not which ones were being expressed. Credit was most commonly awarded to candidates who stated that there would be more copies of mRNA present if the genes were of interest and therefore being expressed. Many candidates made reference to the fact that DNA contained both introns and exons or that DNA was double stranded and RNA single stranded. These did not gain credit as they needed to highlight the identification of the genes of interest.

(c) (i) Most candidates were able to correctly identify that the *t*-test was the most suitable statistical test to use. Many were able to correctly explain that the reason for choosing the *t*-test was that the data was comparing two means, was continuous, or the data would have a normal distribution. The most common incorrect answer seen was that the data was discrete.

(ii) Many candidates needed to use the information provided in the question to help them formulate their null hypothesis and as such did not gain credit. Successful answers stated that there is no difference in the level of gene expression between the *OVT73* and control sheep. The information provided in the question stated that mean count was a standardised value based on the quantity of mRNA transcripts, therefore mean count was accepted as an alternative to level of gene expression. Some candidates referred to gene counts which was not credited as the statistical test was comparing the means between the *OVT73* and control sheep rather than comparing the different genes.

(iii) This question was successfully answered, with many candidates scoring some credit. The most commonly awarded statement was for making a comparison. More successful answers referred to a ratio indicating if the *OVT73* mean count was higher or lower than the control, with a few candidates going on to correctly identify that a ratio of greater than one signified that the *OVT73* mean count was higher than the controls.

(d) Candidates were asked to state one feature of the study which contributed to the validity of the results, so they were looking for one feature of the experiment which suggested the measurements were accurate or the results were repeatable. Successful answers referred to the use of a statistical test or that more than one testing kit was used.

For the second part of this question, candidates were asked to state one feature that would improve the validity of the results. Therefore, they needed to suggest an improvement which could be made which would increase the accuracy of the measurements or the repeatability of the results. This was more successfully answered, with some candidates referring to more sheep or tissue samples being tested.

Several candidates gave their answers the wrong way round and suggested that an improvement would be to perform a statistical test when this had already been done.

(e) (i) The majority of candidates correctly calculated the ratio to achieve an answer of 1.33.

(ii) Many candidates were able to explain that the standard error ranges which overlapped meant that there was no significant difference between the mean urea concentrations. The question asked candidates to make reference to **Table 2.2**, therefore identifying that this was the case for the cerebellum or the motor cortex was needed to gain credit. A few candidates correctly identified that if there was no overlap of standard error ranges for the anterior striatum, this suggested that there may be a significant difference. Those candidates who stated that this meant there was a significant difference did not gain credit, since such a conclusion could only be made if further statistical analysis was carried out.

(iii) Candidates who made reference to the higher urea concentration in the cells, as shown in **Table 2.2**, and explained its relationship to the increase in transport proteins and hence the removal of more urea, gained credit. Many candidates described the relationship by stating that the more urea there was in the cells, the more transport proteins would be present, without explaining that this meant more urea would be removed from the cell, and did not gain credit.

(f) This question provided candidates with possible causes for the increased urea concentrations in cells and asked them to explain why one of these causes was more likely than the other two. Since this question was about the whole study, those candidates who correctly incorporated information given in the stem of the question usually gained credit. The most common correct answer was that no loss of striatal neurones was seen in the *OVT73* sheep. More successful answers referred to more transport proteins being made which meant that more energy was needed by the cell.

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A few candidates stated that the cotton wool would allow gases such as carbon dioxide to escape or trap bacteria and these did not gain credit.

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A few responses suggested that carbon dioxide (from the respiration of bacteria) caused the cloudiness observed. This is incorrect as no limewater was present in the culture tubes.

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Candidates often incorrectly referred to standardised variables such as temperature or the volume of broth culture used. Use of the specification term ‘standardised variables’ rather than ‘control variables’ should help to avoid this misunderstanding.

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Those candidates who chose a serial dilution method often had problems in making their tabulated volumes in the table correct.

(e) This was answered correctly by the majority of candidates. As the dependent variable should be the variable that is measured, 'bacterial growth/population size' did not gain credit. It was the turbidity of the broth culture that is measured in this investigation, so this was the correct dependent variable.

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A risk assessment was required and was attempted successfully by several candidates. Risk assessments should be given in terms of the hazard, the risk associated with that hazard and the appropriate mitigation. For example, broth culture may cause irritation, so gloves should be worn.

(h) (i) Candidates often struggled to write a correct null hypothesis for this investigation. The key point of this investigation was to compare Manuka honey with Germania honey. Therefore, the null hypothesis should state that 'there is no difference in the effectiveness of Manuka honey and Germania honey'. The null hypothesis should not include reference to the concentration of honey.

As the statistical test used was χ^2, null hypotheses that referred to 'no relationship' or 'no correlation' were incorrect. A few candidates gave the alternative hypothesis rather than the null hypothesis.

(ii) Most candidates correctly recognised that the χ^2 values for concentrations 2 and 3 were significant, whilst the χ^2 value for concentration 4 was not significant.

(iii) Several candidates stated correctly that Manuka honey was more effective than Germania honey. To be given full credit for this question, candidates also needed to refer to the statistical analysis regarding the significance of the χ^2 tests. **Table 1.1** indicated that higher concentrations of Manuka and Germania honey showed a significant difference between the number of cultures with bacterial growth. Candidates who noticed this gained credit only if they clearly stated that the significant difference was shown by concentrations 1, 2 and 3. Alternatively, credit was awarded to candidates who noted that there was not a significant difference for concentrations 4 and 5.

Question 2

This question introduced candidates to an unfamiliar investigation on the effect of different diets on lactating Holstein cows.

(a) Many candidates realised that the cottonseed-free diet would allow a valid comparison to be made between the different groups of cows. Candidates needed to then extend their answers to include an explanation of why this cottonseed-free diet would be important. Standardising the diet of the cows or removing gossypol from the cows before the start of the investigation were sufficient to gain credit.

(b) (i) This question asked why the statement made by the candidate was not supported by the data. Therefore, correct answers needed to focus on the data from **Table 2.1**, and not on the overall design of the investigation. Candidates who discussed the dry matter intake of the cows, the small sample size or the age of the cows did not gain credit.

Several candidates noted that the standard error for each group's milk yield overlapped. Some then realised that this overlap in standard error indicated that the milk yields of groups **A**, **B**, **C** and **D** were therefore not significantly different. Few candidates gained credit by stating that the milk yields of different groups were similar. The lack of a statistical test was correctly suggested by some candidates.

(ii) Many candidates noticed the trend that as gossypol in diet increases, the milk yield of the cows also increases, and were therefore able to find evidence to support the candidate's statement. A clear trend was required to gain credit, rather than simply comparing two groups of cows. Several candidates also gave a paired data quote to illustrate this trend, and therefore gained further credit.

Fewer candidates were able to find suitable evidence to not support the candidate's statement. The idea that correlation does not mean causation and the lack of a statistical test were common correct suggestions. The lack of information about the nutritional content of the various diets, or criticism of diet **A** as a suitable control were rarely suggested.

(c) (i) This question was answered correctly by the majority of candidates. A few did not gain credit as they stated that a correlation was present and needed to clarify that the correlation was positive. Additionally, the statement 'as plasma gossypol concentration increases, free gossypol intake also increases' gained no credit as it is the free gossypol that causes plasma gossypol to increase.

(ii) Several candidates stated that diet **E** had the highest risk of gossypol toxicity. References to diet **E** having a higher risk or to several diets being of high risk were not specific enough to be creditworthy. Credit was given for ranking the diets in order of their toxicity from highest to lowest: **E**, **B**, **D**, **C**.

Those candidates who linked the toxicity of different diets to the cow's intake of both free gossypol and (–) isomer gained further credit.

There were many candidates who focused only on the toxicity of the (–) isomer. A paired data quote from **Table 2.2** for either free gossypol or (–) isomer intake allowed candidates to gain further credit.

Some candidates were credited for noting that free gossypol is easily absorbed and is therefore more toxic than bound gossypol. A few candidates suggested that toxicity was linked to the bound gossypol and careful reading of the information given at the start of **Question 2** was necessary to avoid this error.