BIOLOGY

Paper 9700/11
Multiple Choice

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

General comments

The paper differentiated well.

Comments on specific questions

Questions 1, 8, 12, 14, 17, 22 and 30

The largest proportion of the stronger candidates and weaker candidates answered these correctly.

Question 2

Approaching a third of all candidates correctly calculated the actual length of the cell.

Question 3

Approaching a quarter of all candidates correctly realised that if lipids are not removed by the lysosomes they can build up in the cell.

Questions 4, 13, 20, 21 and 31

At least half of all candidates answered these questions correctly.

Question 5, 7, 9, 18, 24, 29, 36 and 38

At least three fifths of the stronger candidates answered these questions correctly, and a small proportion of weaker candidates answered correctly.

Question 6

Whilst almost three quarters of stronger candidates answered correctly, over two fifths of weaker candidates incorrectly suggested that prokaryotic genetic material is not double-stranded DNA.

Question 10

Almost half of all candidates realised that the triglycerides with unsaturated fatty acids would be found more in an oil (liquid) than a fat (solid).

Question 11

Two thirds of weaker candidates incorrectly suggested that covalent bonding was found in the secondary structure of proteins.

Question 15

Nearly a third of all candidates knew that the K_m would not change and the V_{max} would increase.

Question 16

Almost half of all candidates correctly carried out the mathematical processing.

Question 19

Almost three quarters of weaker candidates confused mitosis and the cell cycle.

Question 23

Less than two fifths of all candidates could correctly process the information to obtain the answer of 50 per cent.

Question 25

Almost half of all candidates incorrectly selected option **C**, indicating that they had forgotten that U replaces T in RNA.

Question 26

Whilst almost all of the stronger candidates answered this correctly, the weaker candidates selected each option almost equally, suggesting that they were guessing.

Question 27

*Please note that due to an issue with question 27, this question has been discounted. Each candidate's total mark has been multiplied by a weighting factor so that the maximum mark for the question paper remains unchanged.

Question 28

Over four fifths of all candidates answered this correctly.

Question 32

Nearly a third of all candidates correctly interpreted the data to select option **B** as the correct explanation of the difference in saturation.

Question 33

Approaching a third of all candidates realised that all three statements about the Bohr shift were correct.

Question 34

Whilst over two thirds of the stronger candidates answered this correctly, over a third of all candidates incorrectly suggested that the wave of electrical activity passes through the atrioventricular node before the left and right atria contract.

Question 35

*Please note that due to an issue with question 35, this question has been discounted. Each candidate's total mark has been multiplied by a weighting factor so that the maximum mark for the question paper remains unchanged.

Question 37

Almost half of all candidates answered this correctly. Almost three tenths of all candidates incorrectly selected option **A**. Whilst it is true that the antibiotic resistance increased by more than 20%, there is no data to support the idea that this was due to overuse of ciprofloxacin.

Question 39

Over two fifths of all candidates incorrectly indicated that monoclonal antibodies can be injected into patients to give active immunity. The type of immunity caused by this injection would be passive.

Question 40

Approaching half of all candidates answered this question correctly.

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Paper 9700/12
Multiple Choice

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

General comments

The paper differentiated well.

Comments on specific questions

Questions 1, 5, 6, 10, 12, 13, 15, 18, 20, 24, 26, 28, 29, 32 and 39

These questions were answered correctly by the majority of the stronger candidates and the largest proportion of the weaker candidates.

Question 2

Four fifths of the stronger candidates correctly calculated the answer as 1.5×10^2 nm. Almost two thirds of the weaker candidates incorrectly calculated the answer in μm.

Question 3

Over four fifths of the stronger candidates answered this correctly. Over two thirds of the weaker candidates incorrectly thought statement 2 was correct and therefore indicated options **A** or **D** were correct.

Question 4

A third of all candidates knew that all three listed functions were performed by microtubules.

Question 7

Two thirds of the stronger candidates answered this correctly. Nearly three fifths of the weaker candidates incorrectly selected options **B** or **C**. Since all viruses contain proteins, they must contain peptide bonds which are covalent bonds.

Question 8

Approaching a third of all candidates correctly identified this as a systematic error. Nearly three fifths of all candidates incorrectly believed that the effect of the error would be reduced by performing repeats.

Question 9

The majority of the stronger candidates answered this correctly. Over two fifths of the weaker candidates did not realise that β-glucose is not present in amylopectin and incorrectly selected options **A** or **D**.

Question 11

Less than two fifths of all candidates realised that only molecule D could not be a possible side chain. In the other three molecules, the first carbon atom only has three bonds so can form a fourth bond as they become a side chain.

Question 14

Options **A**, **B** and **C** were selected in almost equal proportions by the weaker candidates, whilst almost four fifths of stronger candidates correctly selected option **B**.

Question 16

Almost half of the weaker candidates incorrectly selected option **A**. It is the water potential of cell P that is the same as the water potential of the surrounding solution, not the sugar concentrations being the same. The plant cell will have many solutes contributing to its water potential.

Question 17

Nearly a third of all candidates answered this correctly. It is a general principle that volume will increase much more rapidly than surface area. Two rapid calculations for cubes of 1 and 2 units in size would show that the surface area to volume ratio would decrease (6 : 1 and 3 : 1).

Question 19

Less than a third of all candidates understood that roles of mitosis were shown in all diagrams. Over half of all candidates incorrectly selected option **D**. Diagram 1 shows asexual reproduction and diagram 2 shows growth of a fruit.

Question 21

Just over a fifth of all candidates answered this correctly. The role of DNA ligase is part of learning outcome 6.1.4. Over half of all candidates incorrectly selected option **A**. This is incorrect because the strands are antiparallel, not parallel.

Question 22

Nearly a fifth of all candidates answered this correctly. The differences between the leading and lagging strands was found to be a difficult concept.

Question 23

Two fifths of all candidates could use the information provided to determine that **C** was the correct option.

Question 25

Approaching two fifths of all candidates were able to identify the correct functions for the xerophytic adaptations shown in the diagram.

Question 27

A quarter of all candidates correctly selected option **B**, whilst almost half of all candidates incorrectly selected option **C**. Candidates needed to know that sucrose is moved from mesophyll cells into companion cells via cotransporter proteins against the sucrose concentration gradient. The sucrose then diffuses from companion cells to phloem through the plasmodesmata.

Question 30

This was answered correctly by over four fifths of all candidates.

Question 31

Over two thirds of the stronger candidates answered this correctly. The weaker candidates found this to be a difficult concept and less than three tenths of the cohort were able to answer correctly.

Question 33

Nearly a third of all candidates answered this correctly. Although the diagram shows blood pressure changes in the left side of the heart, similar but lower pressure changes would be seen in the right side of the heart. Candidates needed to recognise that systole is the contraction phase and then use the graph to determine when atrial and ventricular contraction occur.

Question 34

Whilst the majority of stronger candidates were aware that some bronchioles may contain goblet cells, meaning that the correct option was **D**, seven tenths of the weaker candidates incorrectly thought that goblet cells were present in all bronchioles.

Question 35

Three quarters of stronger candidates and a third of weaker candidates answered this correctly. Almost three fifths of weaker candidates incorrectly thought the image was from a transmission electron microscope rather than from a scanning electron microscope.

Question 36

Almost all candidates answered correctly.

Question 37

This was answered correctly by almost half of all candidates. Two fifths of the weaker candidates incorrectly selected option **C**. It must be true that molecule Y cannot be released from cells of organism X since the bacteria surrounding the top left hand well had not been killed.

Question 38

Two fifths of all candidates answered this correctly.

Question 40

Whilst almost four fifths of the stronger candidates answered this correctly, the largest proportion of weaker candidates selected option **A**. Each antibody can only bind to one type of antigen, therefore both antigen binding sites are identical.

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Paper 9700/13
Multiple Choice

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

General comments

The paper differentiated well.

Comments on specific questions

Questions 1, 2, 4, 6, 8, 9, 16, 17, 19, 20, 21, 26, 27, 30, 31, 33, 36, 37, 39 and 40

These questions were answered correctly by at least four fifths of the stronger candidates and the largest proportion of the weaker candidates.

Questions 3 and 11

At least nine tenths of all candidates answered these questions correctly.

Question 5

Almost three fifths of the weaker candidates and a fifth of the stronger candidates were unable to select the correct description of plasmodesmata.

Question 7

Over a half of all candidates incorrectly selected options containing statement 2. Since prokaryotes typically have a circular chromosome and no nucleus, they cannot undertake the process of mitosis.

Question 10

Three quarters of the stronger candidates and a quarter of the weaker candidates answered correctly, selecting option **A**.

Question 12

Over two fifths of all candidates incorrectly selected options containing process 3. Allowing leaves to cool down quickly at night is not a process in which hydrogen bonding in water is important on hot sunny days.

Question 13

Three quarters of the weaker candidates answered this question incorrectly. Candidates needed to understand that the many hydrogen bonds linking the unbranched chains of β-glucose result in the cellulose fibres having great strength.

Question 14

Over three fifths of all candidates did not realise that all three statements correctly described enzyme actions.

Question 15

Almost a fifth of the weaker candidates incorrectly believed that the active site had the same shape as the substrate. Almost half of all candidates incorrectly thought that statement 2 was correct.

Question 18

Nearly a third of all candidates realised that all four statements comparing endocytosis and exocytosis were correct.

Question 22

Just over half of all candidates could correctly describe the structure of lagging strands. Over half of the weaker candidates incorrectly suggested these strands consisted of more than one polypeptide chain and only contained carbon, hydrogen, oxygen and nitrogen, forgetting the presence of phosphate.

Question 23

Whilst over four fifths of the stronger candidates answered correctly, almost three fifths of the weaker candidates incorrectly selected option **D**. This is the mRNA codon, not the tRNA anticodon.

Question 24

Half of all candidates were able to use the information provided to correctly obtain the answer of 60%, option **D**.

Question 25

Whilst the majority of stronger candidates answered this correctly, almost a third of all candidates incorrectly selected option **A**. Xylem vessel elements are hollow vessels but they only allow the movement of water up a plant.

Question 28

Almost three fifths of all candidates answered this correctly.

Question 29

Almost all of the stronger candidates answered this correctly. Whilst nearly four fifths of the weaker candidates correctly identified the neutrophil, over two fifths confused the lymphocyte and monocyte.

Question 32

Almost all of the stronger candidates and a third of the weaker candidates answered correctly, showing an understanding of the chloride shift.

Question 34

Three quarters of the stronger candidates correctly identified the photomicrograph as being a section of bronchus. Almost three tenths of weaker candidates thought the structure was an alveolus and a third thought the structure was a trachea.

Question 35

Over two fifths of all candidates answered correctly. The key determinants for efficient diffusion are a maintained concentration gradient, a maximised surface area and a minimised diffusion pathway.

Question 38

Almost three fifths of all candidates were able to process the information correctly. Nearly three tenths of all candidates incorrectly indicated that the data supported statement **A**. A fifth of the weaker candidates incorrectly thought statement **D** was supported by the data, even though the results only covered five days.

BIOLOGY

Paper 9700/21
AS Level Structured Questions 21

Key messages

Candidates need to be able to apply their understanding of concepts on the syllabus to unfamiliar examples, such as in **Question 2(b)(iii)**, which required application of understanding of cell signalling to the unfamiliar signalling molecule ghrelin. Similarly, **Question 4(c)** required application of understanding of the cardiac cycle to the unfamiliar heart condition, cardiac tamponade. Candidates who have the opportunity to practise these skills throughout the course will benefit when tackling exam questions such as these.

Candidates should be able to analyse data and suggest biological explanations for the patterns they see. When answering **Question 6(b)(ii)**, many candidates could have improved their response by using knowledge about the modes of action of enzymes from the syllabus to suggest ways in which an aptamer may have reduced the V_{max} of the enzyme.

It is important that candidates learn the exact scientific names of cells and organisms. **Question 3(a)** required candidates to identify a cell type found in plant tissue transporting assimilates. Many candidates wrote inaccurate names such as 'phloem cell' or 'phloem sieve cell'. **Question 4(a)** asked candidates to state the full name of the pathogen HIV and inaccurate names such as 'human immune virus' and 'human immuno virus' were seen.

General comments

Overall, there were good answers to many of the questions on the paper. Candidates who had prepared thoroughly for this exam gave a very good all-round performance. Others showed gaps in their knowledge, making it harder to gain full credit in extended responses such as **Question 2(b)(iii)**, **Question 3(c)** and **Question 4(b)**. It is important that candidates identify the key ideas needed to answer each question before starting to write so that they can manage their time effectively across the whole exam paper.

Candidates need to take time to carefully read all of the stimulus material provided in each question before planning an answer. The introduction to **Question 3** provided information about two cells found in plant tissue. This information should have allowed candidates to realise that the cell types in the question were eukaryotic and rule out the possibility that cell type **A** was a prokaryotic cell. This was a common incorrect answer; these candidates may have related the lack of a nucleus in the cell with the idea of prokaryotes lacking a true nucleus. Candidates need to check their answers carefully before moving on to another question.

Familiarity with electron micrographs will help candidates be more successful when presented with these images in exam papers. **Question 2(a)** required candidates to outline the roles of structures shown in an electron micrograph. Some candidates found this question less challenging than others because they were able to identify the structures. Candidates can use images of electron micrographs to practise identification of cell structures.

Candidates need to take care to use biological terms accurately. In **Question 3(c)**, some candidates confused the terms cohesion and adhesion, and few made reference to the transpirational pull. In **Question 4(c)**, weaker candidates wrote about contraction of the heart rather than making more accurate reference to contraction of the ventricles. In **Question 5(a)(ii)**, it was important for candidates to refer to contraction of the smooth muscle rather than contraction of the bronchus. In **Question 5(b)(ii)**, candidates gained credit for describing the role of cholesterol as regulating the fluidity of the membrane rather than for suggesting that cholesterol controls the fluidity of the membrane.

Comments on specific questions

Question 1

(a) (i) Candidates needed to use knowledge and understanding of active transport as well as the information in **Table 1.1** to answer this question. The strongest answers named active transport as the process and then explained how the data in **Table 1.1** supported this conclusion. Candidates who made reference to the sodium-potassium pump were able to gain credit for their understanding of its involvement in active transport. Some candidates interpreted the information in the table incorrectly and concluded that the process was diffusion.

(ii) This was a challenging question for the majority of candidates. The strongest responses used the data in **Table 1.1** to deduce that sodium ions enter red blood cells down a concentration gradient. Candidates then had to use their knowledge of diffusion to recognise that oxygen can enter by simple diffusion but sodium ions, which are charged, enter by facilitated diffusion. Some responses suggested that sodium ions could move into the red blood cell by facilitated diffusion and by active transport and gained credit for this suggestion. Some candidates introduced contradictions when describing differences, for example stating both enter by diffusion and then also stating that sodium ions use energy from the cell to enter.

(iii) The strongest responses showed an understanding that chloride ions enter red blood cells during the chloride shift and hydrogencarbonate ions diffuse out. A few of these went on to explain that this process occurs to maintain electrical neutrality in the red blood cell. Many gave only one idea although the allocation of two marks meant that for full credit at least two correct points needed to be made. Some candidates described the formation of carbonic acid and the production of hydrogencarbonate ions. This was not needed to answer the question because this process does not explain the importance of the chloride shift. Some of these candidates gained full credit by including other correct points.

(b) Endocytosis was given by many. The most common incorrect answer was osmosis. Candidates had to use the information in the question stem and deduce that the invagination of the cell surface membrane was due to the formation of vesicles during endocytosis.

Question 2

(a) This question was well answered by many candidates. They needed to study the transmission electron micrograph carefully and identify the functions of structure **X**, the nucleolus, and structure **Y**, the chromatin in the nucleus. Some candidates correctly identified these structures and were unable to gain credit without accurately describing their functions. Some described the process of transcription when attempting to outline the role of structure **Y**, and while this was not required, candidates were able to gain credit for their knowledge.

(b) (i) The majority of candidates correctly identified the level of protein structure shown in **Fig. 2.2** as the primary structure. The most common incorrect answer was tertiary structure.

(ii) The strongest responses identified the carboxyl group as a similarity between the fatty acid molecule and the amino acid molecule. Some candidates expressed this by stating that both molecules contained C=O and were given credit for their understanding of the chemical structure of this group. Reference to the presence of a double bond was not sufficient to gain credit as candidates needed to accurately identify the carboxyl group. A common incorrect answer was reference to hydrogen bonding. Some candidates made reference to carbon-to-carbon bonds and were given credit for recognition that both molecules contain carbon.

(iii) Some candidates were able use their knowledge of cell signalling and their knowledge of protein structure to suggest suitable reasons for the fatty acid on the ghrelin molecule. Answers that gained credit recognised that the fatty acid played a role in the binding of ghrelin to a receptor. Those who identified that it would facilitate binding to a cell, needed to make reference to receptors to gain credit. The strongest candidates included further detail in their answers. For example, they described the effects that binding would have in the cell, such as initiating a signalling cascade. A common incorrect suggestion was the idea that the addition of the fatty acid formed a glycoprotein. Many candidates found this a demanding question.

(c) (i) The most accurate responses used 30 codons to obtain the correct answer because they recognised that the start amino acid in **Fig. 2.2** was not met. This allowed them to perform a calculation that included the start codon, the 28 codons for the amino acids in ghrelin shown in **Fig. 2.2**, and a stop codon. This gave a value of 1.8%. Some candidates needed to read the question more carefully as they gave their calculated answer to more than the required number of decimal places.

(ii) There were some excellent descriptions of modification of the primary transcript, which correctly used the terms intron, exon and RNA splicing. Some candidates gained credit for their understanding of the removal of introns and needed to go on to clearly describe the next step of joining the exons to produce the mRNA molecule. The answer 'extrons' was not acceptable for exons. Some candidates incorrectly identified the molecule that the introns are removed from as mRNA. Statements such as 'leaving the exons', without reference to them being joined, did not gain credit. Candidates must qualify the type of spicing that takes place during this process by referring to RNA splicing or gene splicing rather than 'splicing' alone.

Question 3

(a) Some candidates used the data in **Table 3.1** effectively to identify cell type **A** as a sieve tube element. A common incorrect answer was to identify the cell as a prokaryote cell although the question clearly stated that the cells were found in plant tissue and must therefore be eukaryotic cells. Some candidates incorrectly identified the cell as being found in xylem tissue. Candidates who were able to identify the role of the plasmodesmata described the symplast pathway. The strongest responses gave examples of assimilates, such as sucrose, that are transported between cell type **A** and cell type **B** and used appropriate scientific language to describe the method of movement. Credit was not given for repeating information in the question stem and stating that plasmodesmata are an adaptation for the efficient transport of assimilates.

(b) The majority of candidates were able to identify the bond between the monomers in **Fig. 3.1** as a 1, 3 glycosidic bond. Many also recalled that the monomer in cellulose is beta glucose. Fewer candidates recalled that a cellulose molecule is a straight chain, confusing it with amylose molecules and describing it as helical. Many candidates found it challenging to recognise that the monomers in callose shown in **Fig. 3.1** were all orientated the same way up, which contrasts the alternating pattern seen in the cellulose molecule.

(c) Some candidates showed knowledge of hydrogen bonding between water molecules and were able to use the term cohesion correctly. A few candidates confused the terms cohesion and adhesion. These responses were given partial credit for their knowledge of these terms. The strongest answers explained the importance of cohesion in the transport of water, making reference to a column of water being pulled up the xylem vessel and using the term transpiration pull. A few candidates also gained credit for their knowledge of adhesion. It was important for candidates to show understanding of hydrogen bonds forming with cellulose or hydrophilic parts of lignin in the xylem vessel wall, rather than simply stating that there was adhesion to the wall.

(d) The highest achieving answers to this question linked knowledge of cohesion between water molecules and knowledge of the high latent heat of vaporisation of water to explain the need for energy to break hydrogen bonds between water molecules. Some candidates were able to gain credit for their descriptions of heat energy being lost from the leaf when water evaporates, even if they needed to explain why that heat energy was needed. Weaker answers simply suggested that the water was heated without an explanation of where the energy came from to heat the water, or suggested that heat energy in the water simply disappears, cooling the leaf, without providing any further explanation.

Question 4

(a) (i) A good proportion of candidates were able to state the full name of the pathogen HIV and many spelt this correctly. Weaker responses included names such as 'human immunity virus' and these were unable to gain credit.

(ii) The majority of responses identified the decrease in the percentage infections in most regions of the world. Some went on to identify exceptions to this trend. The strongest responses used data from **Fig. 4.1** to support the decrease that they described and identified areas with the smallest or

largest percentage decrease. Weaker responses provided a list of countries and percentages, and these were able to gain some credit for their use of data. Some candidates misunderstood and reviewed the number of infections in each area rather than the decrease in infections required by the question, which asked candidates to consider changes in number of new infections. Some candidates wrote about how HIV is controlled, suggesting control measures that might have been used to achieve the decreases they saw in the data. This was not relevant to the question as there was no data provided on control measures so no conclusion about these can be drawn from the data in **Fig. 4.1**.

(b) Most were able to show an understanding that a person with HIV/AIDS has a weakened immune system. A very few went on to describe the aspects of the primary immune response that would be affected, such as the secretion of less cytokine as a result of fewer T-helper cells. Some candidates showed understanding of tuberculosis (TB) as an opportunistic infection and gained credit for this. Candidates also showed knowledge of the cause of TB by correctly naming the causative pathogen or identifying it as a bacterial pathogen. Some candidates made suggestions, such as a poor response to vaccination for TB, and these ideas were also credited. Weaker answers described a complete lack of an immune response, such as no B-lymphocytes or no phagocytosis, rather giving descriptions that implied fewer lymphocytes or decreased phagocytosis.

(c) Candidates were not expected to have learned about cardiac tamponade, and all reasonable suggestions were credited. Those who did well showed a clear understanding of how a healthy heart circulates blood throughout the body. It was important for candidates to be specific about the steps in the cardiac cycle and to make reference to phases, such as ventricular systole or contraction of the ventricles, rather than simply describing the heart contracting less forcefully. Some candidates successfully described the compression of the ventricles shown in **Fig. 4.2** and recognised that this would affect the ability of the ventricles to fill completely. Weaker responses such as 'the heart is not pumping blood as efficiently' or 'ventricles are not working efficiently' were unable to gain credit. Many candidates gained credit for suggesting explanations for the increase in breathing rate.

Question 5

(a) (i) A significant proportion of candidates identified tissue **T** as cartilage. Many were able to spell this term correctly. Incorrect responses included muscle tissue and epithelial tissue.

(ii) Most candidates who gained credit recognised that smooth muscle in the wall of the bronchus is able to contract, and a few were able to develop their answer to explain the role of contraction of the smooth muscle. Common errors were to confuse the function of smooth muscle with elastic tissue and describe stretch and recoil, or to suggest that the bronchus itself contracts rather than the smooth muscle in the wall of the bronchus.

(b) (i) This question was well answered by many candidates who showed a clear understanding of the arrangement of phospholipids in a membrane. Some candidates drew a single layer of phospholipids rather than a bilayer and gained credit for their knowledge of phospholipid structure only. Some candidates confused the structure of a phospholipid with that of a triglyceride and drew three fatty acid tails rather than two. Some diagrams showed the phospholipid bilayer drawn as a completed circle showing the entire lamellar body. This was not required by the question and candidates are reminded to ensure that the accuracy of their drawing of each phospholipid is maintained, should they choose to draw a large number of the molecules.

(ii) Generally, there was a good understanding that cholesterol has a role in in regulating the fluidity of membranes. Responses of the highest standard linked this to the formation of vesicles for exocytosis. Some candidates misinterpreted the question and suggested that a reduction in cholesterol in the membrane would reduce synthesis of surfactant because this also contains cholesterol. Candidates needed to read the question carefully as the stimulus material at the start of the question described the synthesis of surfactant in the rough and smooth endoplasmic reticulum and then in the Golgi body, not the cell surface membrane.

(iii) Some candidates made good suggestions as to why macrophages engulf surfactant. For example, a number suggested that macrophages were able to recycle the biological molecules in surfactant, releasing molecules such as cholesterol and proteins for reuse. The most common incorrect idea

was to suggest that surfactant acts as a non-self antigen. Candidates who suggested that there were non-self antigens or pathogens trapped in the surfactant were given credit for their ideas.

Question 6

(a) (i) A high proportion of candidates correctly identified the S phase. The most common mistake was to name a stage of mitosis such a prophase or metaphase.

(ii) Candidates were not expected to be familiar with the structure of the modified nucleotide and needed to apply their knowledge of DNA structure and condensation reactions to deduce the answer to this question. Most who gained credit recognised that the structural difference in the nucleotides would prevent the formation of a phosphodiester bond. Some developed this idea and made reference to the condensation reaction being unable to occur. Some answers lacked sufficient detail to gain credit for the ideas presented, such as 'without the O in the –OH group a bond cannot be created'. A few candidates thought about the change in shape that would result from the change in structure of the nucleotide and linked this to the importance of shape to enzyme action. Some candidates confused the structure of the modified nucleotide with the structure of ribose.

(b) (i) Many candidates correctly linked the increase in K_m with a decrease in affinity of RNA polymerase for its substrate. The strongest answers also considered each of the two aptamers separately and identified the aptamer which was most effective at reducing the affinity of the enzyme for its substrate. A few candidates realised they needed to consider K_m and incorrectly described an increased affinity for the substrate. Weaker answers tried to use V_{max} to draw conclusions about the affinity of the enzyme for the substrate.

(ii) This question asked candidates to consider the rate of transcription and many recognised that they therefore needed to consider the V_{max} that was achieved in the presence of each aptamer. Few candidates where able to develop their ideas to suggest explanations for the reduction in V_{max}. The most common correct explanations were those linked to how an enzyme works, such as suggested changes in the shape of the active site of the enzyme or a possible reduction in the number of enzyme-substrate complexes formed.

BIOLOGY

Paper 9700/22
AS Level Structured Questions 22

Key messages

It is important that candidates carefully check the instructions associated with each question. **Question 1(b)** required candidates to complete **Fig. 1.1** to show the metaphase stage of mitosis. Only two chromosomes should have been included in the drawing and the diagram should have been labelled. Some made the error of drawing too many chromosomes, while others needed to add labels to the diagram.

Some questions require candidates to use data from graphs to help them produce a complete and accurate response. In **Question 2(e)**, there were two graphs related to the activity of protease enzymes, **Fig. 2.1** for temperature and **Fig. 2.2** for pH. Discussion points should have included data extracted from both graphs, and for the correct units to be included where relevant.

The introns that form part of the primary transcript of a gene should be described as non-coding sequences and the exons as coding sequences. In **Question 4(d)(ii)**, although many candidates used the term 'sequences' or other appropriate terms, there were others who gave incorrect descriptions of introns. These included the terms 'triplets', 'nucleotides', 'bases' and 'codons'.

General comments

A very good all-round performance was given by a number of candidates. These respondents were able to identify the main points to make when asked questions assessing knowledge of syllabus topics and understood the depth of answer required to gain full credit. They were also skilled in handling information to apply their knowledge, such as in dealing with the new contexts of keratin in **Question 2**, hepatocytes in **Question 3** and surfactant in **Question 4(c)** and **Question 4(d)**.

Generally, candidates made a good effort to include the correct scientific terminology in their responses.

It is important that candidates read questions very carefully. **Question 1** was based on the mitotic cell cycle. In **Question 1(b)**, some used up valuable time writing about metaphase, anaphase and telophase.

In Question 2(c), candidates could use the information provided and apply knowledge learned in Topic 2, Biological molecules, to suggest features of keratin structure that contribute to its stability. Some needed to read the question properly and described collagen instead.

Candidates should not use abbreviations for rough endoplasmic reticulum and smooth endoplasmic reticulum when trying to identify and describe these structures for the first time. It is acceptable to use RER and SER once the full term has been written out. Some candidates needed to give the full terms for these structures in **Question 3(c)(i)**.

Question 4(c) introduced a transport protein used for the transfer of surfactant phospholipids from the cytosol into the lamellar body. Active transport was indicated by the name of the protein, which included the term 'ATP-binding'. More perceptive candidates were able to do well and describe the features of carrier proteins for active transport.

Candidates were not obliged to use the space in **Question 5(e)** to draw a diagram of an elastic artery. Some who did so gave a cross section, labelled the three layers, and indicated the location of the large proportion of elastic fibres. This meant that when they wrote about damage to elastic fibres, they were given credit for knowing the location in the artery of the fibres, which helped to give a more complete response.

In **Question 6**, **Fig 6.1** was provided as stimulus material to remind candidates of the function of xylem tissue and the requirements for efficient functioning, and to help prevent them from going into the functioning of phloem sieve tubes. Weaker responses copied the information to add to their answers for the part-questions that followed, without providing any further qualification that would be creditworthy.

Comments on specific questions

Question 1

(a) Almost all candidates attempted to complete **Fig. 1.1**. Many knew that histone proteins were complexed with DNA. There was a wide range of incorrect answers such as amino acids, chromatin, chromosome, nucleotides, globular, and proteins that have been covered in the syllabus such as cytokines and capsids.

(b) Some took great care drawing the diagram of two chromosomes in the metaphase stage of mitosis, including orientating the chromosomes correctly at the spindle equator (metaphase plate), with sister chromatids facing opposite poles. Some noted that this was an animal cell and drew a pair of centrioles at each pole, orientated at the correct angle to each other. Centromeres were included on the chromosomes and were shown attached to spindle fibres. It was important to label the diagram to gain full credit. The standard of diagram drawing seen varied. In weaker responses, the spindle was frequently not included, and some drew separated chromatids, homologous chromosomes, or more than two chromosomes. A common error in labelling was to label the centrioles as centromeres. Kinetochores are different structures to centromeres and for the labels, kinetochore was not acceptable for the centromere.

(c) An outline of chromosome behaviour in only a part of the cell cycle was required. Some gave concise answers and made at least three relevant points to gain full credit. Many candidates knew that DNA replication occurred in the S phase, fewer stated that this resulted in the formation of two sister chromatids, and a minority included the involvement of histone proteins in the formation of the chromatids. Some were clear in stating that chromosome condensation occurred in prophase, and others incorrectly thought this began in the G_2 phase. Connection of spindle fibres to the centromere of chromosomes occurs in prophase and this was correctly noted by a few candidates.

Some candidates gave confused responses, using the terms chromosome, chromatid and chromatin incorrectly or used them interchangeably. Using the term chromatin was acceptable to describe the diffuse chromosome in interphase, either before or after the S phase, but not for the condensed chromosome visible as being composed of two sister chromatids in prophase. Those candidates who tried to give a complete outline of chromosome behaviour through to telophase often missed out the S phase and prophase and gave only one or two points that could be credited. Many gave details of checkpoints, and this was not required.

Question 2

(a) Most deduced from the description given that secondary structure is used to classify keratin.

(b) Many gave an acceptable suggestion of how a protease can act on different substrates. Some used their knowledge of competitive inhibitors to suggest that the protein substrates had similar shapes so that they had a complementary shape to the active site of the protease. Others applied their understanding of induced fit to suggest that the enzyme active site could change shape to allow different substrates to bind. A small number suggested that larger proteases may have more than one active site and quite a few noted that it is the peptide bond that is hydrolysed.

(c) Candidates were asked to consider features contributing to the stability of keratin. The most common point put forward was the existence of the covalent disulfide bonds. Hydrogen bonds were also frequently mentioned, with only a proportion correctly identifying that collectively many hydrogen bonds were providing the stability required. A common error here was to state that hydrogen bonds are strong bonds. Some used knowledge of collagen structure to give them ideas, for example, stating that keratin is a fibrous, insoluble protein. Credit was not awarded for giving a description of the structure of collagen. Some responses used the term ‘collagen’ instead of ‘keratin’ in their response.

(d) **Table 2.1** was often correctly completed. The most frequent error was to inaccurately extract data from **Fig. 2.1** and state the lower temperature of A22 as 37 °C. Some candidates did well in completing the table correctly and when completing the blank spaces below the table, they gave temperature and pH values rather than naming the keratinases involved.

(e) Good answers used values accurately extracted from **Fig. 2.1** and **Fig. 2.2** to discuss advantages and disadvantages of the two keratinases as enzymes for washing detergents. Some candidates had noted the information that keratinases suitable for washing detergents should function well in alkaline conditions and decided to discuss only the results for pH, even though the question asked them to refer to both figures. Weaker responses gave statements about the enzymes being able to work in alkaline conditions and at particular temperatures and needed to support these with data. Others wrote about enzyme denaturation, even though the graphs showed activity at the pH or temperatures stated. Some compared all three enzymes, which was not required.

Question 3

(a) The majority named the aorta as the main artery, with most giving the correct spelling. The most common error was to name the pulmonary artery.

(b) (i) Some used the information given to suggest a sensible advantage of having large gaps between the endothelial cells of the sinusoids, such as allowing the passage into the sinusoids of the larger plasma proteins produced by the hepatocytes. Smaller substances such as oxygen, glucose and amino acids would be able to move from the sinusoids through the endothelial layer of cells to the hepatocytes, so stating that the gaps meant these substances could pass through to the hepatocytes was not giving an advantage. Here it was important to note that an advantage would be easier transport of the substances to the cells, or a faster overall rate of movement. Some had noted that the Kupffer cell was a phagocytic cell, so used their knowledge to suggest the cell could squeeze through the gap into the tissue fluid. Weaker responses gave short answers, such as ‘easier to pass across’ and needed to qualify with any examples of substances that would be transported. Others made errors and wrote about substances passing from the sinusoid into the Kupffer cell or into the endothelial cell.

(ii) This was very well answered by a large proportion of candidates, with many written to a high standard. These gave a sequential description and used correct scientific terminology. Most candidates understood that the lysosome contained the hydrolytic enzymes and that the organelle fused with the phagocytic vacuole containing the red blood cell. Less clear answers stated that the lysosome fused directly with the red blood cell, while others only noted that the Kupffer cell had hydrolytic enzymes. Some weak answers misunderstood and gave accounts of the specific immune response involving B-lymphocytes and T-lymphocytes.

(c) (i) Some of the strongest answers related five cell structures in **Fig. 3.2** to the function of the hepatocyte. These were the labelled glycogen granules and the lipid droplet and the three visible, unlabelled, cell structures: the mitochondria; the smooth endoplasmic reticulum (SER) and the rough endoplasmic reticulum (RER). Credit was only given if the organelles were also correctly labelled on **Fig. 3.2**, which some candidates missed. Candidates were able to locate RER more successfully than SER. The majority of SER appears in the top left section of **Fig. 3.2**. A common error was to label the RER located in the bottom right quarter of **Fig. 3.2** as the Golgi body. Misconceptions about the function of the mitochondrion shown by some candidates were to state that energy is produced or that it is the storage site for ATP.

(ii) The majority gained credit for stating one difference, visible in **Fig. 3.2**, between the peroxisome and a mitochondrion. Most realised it was not possible to identify with certainty the ribosomes or the circular DNA in any of the mitochondria, and so gave a clearly visible difference that could be credited. A high proportion cited the double membrane of the mitochondrion, with fewer noting the presence of the cristae. A common error was to name the cristae incorrectly as cisternae.

(iii) Candidates who gained full credit suggested two relevant reasons why only a mitochondrion can synthesise enzymes. A higher proportion stated the presence of 70S ribosomes in mitochondria than the presence of DNA. Reference to the ability to produce ATP was also frequently seen. Some needed to use better expression for this, rather than statements such as ‘making energy’, to gain credit. It was also not correct to state that a mitochondrion stores energy.

(iv) Candidates were expected to understand the hazards of hydrogen peroxide from learning about the reaction catalysed by catalase in Topic 3, Enzymes, and there were many who showed an understanding of the role of the peroxisome in protecting the rest of the cell. Stronger answers suggested the possible damage to the cell that could result from the toxicity of hydrogen peroxide. Some also used their knowledge of the reaction to suggest a useful role for the oxygen produced from the reaction. Good answers also wrote about benefits to a cell of compartmentalisation in terms of increasing the efficiency of metabolism. Weak responses wrote about harmful products of the reaction. There were others that suggested an effect on the water potential or pH of the cell, and these were usually not accompanied by a correct context. More general effects to the body were unable to be credited.

Question 4

(a) In this question, it was important to focus on blood flow in the alveolar capillaries so that an explanation could be given about how steep diffusion gradients could be maintained. While there were some very clear, well-expressed answers, many only gave an account of gas exchange or wrote about the features of a good gas exchange surface, which was not required. The most comprehensive answers covered the maintenance of a steep gradient for both respiratory gases, oxygen and carbon dioxide. Of those candidates who understood that the focus of the question was on the flow of blood rather than a static situation, more gave detail about the blood arriving at the alveolar area. Far fewer noted that newly oxygenated blood was then taken away in the blood flow.

(b) The use of the correct scientific terminology was essential here. Candidates who used the terms ‘contract’ and ‘relax’ rather than ‘stretch’ and ‘recoil’ were only able to gain credit if they showed an understanding that part of the role of the elastic fibres in the wall of the alveoli is to prevent bursting of the alveoli on inhalation. Some who used the correct terminology would have benefited from checking to see that the ‘stretch’ was related to inhalation and the ‘recoil’ related to air leaving the alveoli on exhalation, as there were a number who got this the wrong way round.

(c) A number realised that this unfamiliar context of transport across membranes was an example of a protein carrier that functioned in the active transport of surfactant phospholipids across the membrane of the lamellar body. These candidates usually provided enough correct information to do well. The focus of assessment was knowledge of the features of proteins involved in active transport. Some realised that ABCA3 was a transport protein and missed the very important point that ATP was involved and incorrectly thought that this was facilitated diffusion. Here, it was still possible to gain credit for a point that could also be applied to the protein, such as stating that the protein had a specific binding site for the surfactant phospholipid. Many others needed to read the question more carefully and gave answers that could not be credited, such as discussing about the hydrophobic and hydrophilic structure of the membrane or writing about bulk transport across the membrane. Some weak responses suggested that the phospholipids were part of the membrane, rather than molecules that would form part of the surfactant.

(d) (i) A very large majority gained full credit. Some wrote transcription for **Y** and translation for **X** and were given some credit. The incorrect terms for these processes included translocation, transpiration, replication and mitosis.

(ii) A number of excellent answers were seen from candidates who clearly had a good understanding of post-transcriptional modification and realised that the degenerate nature of the genetic code was not relevant to this question. The fact that more than one codon can specify for the same amino acid would not explain the differences in the number of base pairs in gene *ABCA3* and the number of amino acids in protein ABCA3. Knowledge of introns and exons has increased, and a good proportion knew that introns would be removed from the primary transcript. Some could have improved their description of an intron by stating that it is a non-coding sequence of nucleotides. Using the term ‘messenger RNA’ or mRNA should be reserved for the RNA obtained after splicing of the primary transcript has occurred, that is, the RNA containing only exons. Reference to a stop codon was not credited if candidates suggested that the amino acid sequence was shorter, implying that this was a premature stop codon. Fewer mentioned the start codon to suggest that the first amino acid translated, methionine, may be removed. Most who were unable to gain credit gave an account of the degeneracy shown by the genetic code.

Question 5

(a) Most remembered that *Mycobacterium bovis* is the other species involved in the transmission of tuberculosis (TB). Candidates who gave the species already named as well as *M. bovis* did not gain credit.

(b) Many candidates correctly noted that milk from infected cattle should be pasteurised to help prevent the transmission of the pathogen. The situation stated in the question was about people drinking milk taken from infected cattle, so those who suggested that the infected cattle should be treated or tested were not answering the question posed. Vaccination of people against the disease has not proved effective for all, so this suggestion was treated as a neutral idea and those that also suggested pasteurisation were credited.

(c) Airborne droplets cannot cause disease unless they contain the infectious pathogen. Many candidates remembered to explain that the airborne droplets breathed or sneezed out etc. from the infected person would contain *Mycobacterium*. Full credit was gained when transmission by inhalation of these airborne droplets was explained. Some used the term aerosol infection or droplet infection as part of their response, which was acceptable to indicate airborne droplets containing pathogen. Weak responses described contact infection or wrote about contaminated food being ingested. Some answers incorrectly used the name of the disease as the name of the causative organism and incorrectly stated that TB was the infectious pathogen.

(d) Most stated antibiotics as a treatment for latent TB infections. For a complete answer, it was necessary to show an understanding of antibiotic combination therapy or give another correct detail. Some candidates just wrote 'use ACT' and needed to write out the full term for the abbreviation. Some also knew one or more of the antibiotics commonly used or could give a correct explanation of the length of treatment required. Others stated vaccination as a treatment, which would not be successful because the pathogen remains within human cells.

(e) Many showed an understanding that the high blood pressure in the elastic artery would be able to cause a rupture of the blood vessel if the artery wall was affected by *M. tuberculosis* infection. Some gave really clear diagrams of a section through the artery, labelling the tunica intima, the tunica media and the tunica externa (adventitia). Annotating the diagram with the location of the elastic fibres, smooth muscle and collagen fibres was also helpful in confirming knowledge. Most who did well made it clear that the loss or damage to the elastic fibres, which formed the major part of the tunica media, would affect the ability of the artery to function correctly. As with elastic fibres in the alveoli, references to an inability to contract and relax were not credited. Some confused elastic arteries with alveoli and wrote about bursting during inhalation. Others suggested that holes would appear in the artery wall, causing water to enter and burst the artery.

Question 6

(a) Xylem vessel elements were known by a number of candidates. Otherwise, a wide range of incorrect names were seen. These commonly included lignified cells, sclerenchyma, xylem tube cells, xylem cells, dead cells, sieve tube elements, tracheids and mesophyll cells.

(b) Transpiration pull was frequently included in the answer for this question, and many also showed an understanding of the importance of the cohesive and adhesive forces of water. Some could have improved their description of water loss in the leaf, for example by stating that evaporation of water occurred from the surface of the spongy mesophyll cells rather than stating this was from the mesophyll cells, or from the stomata, or the surface of the leaf.

(c) (i) There were some good answers to this question. Candidates needed to relate lignification to the concept of structure to function of xylem vessels. Reference to the waterproof nature of lignin and helping to prevent the collapse of xylem vessels were the two most common points given. Adhesion of water molecules to lignin was not credited unless it was noted that this occurred with the hydrophilic parts of lignin.

(ii) Most were able to answer this question correctly and a wide range of acceptable answers were seen.

BIOLOGY

Paper 9700/23
AS Level Structured Questions 23

Key messages

Candidates often needed to assimilate the information provided in the stems of the questions, and to read the wording of the questions carefully. Some were able to do this successfully, and others could have improved their answers by reading all of the information provided, including the main introduction to the whole question, before starting each of their responses. In **Question 1(a)**, some wrote about nuclei instead of daughter cells, having missed the information given before **Fig. 1.1**. In **Question 2**, many candidates thought that the enzyme starch phosphorylase was involved in a breakdown (catabolic) reaction although the description of its action given in the question clearly contradicted this idea.

There were many opportunities to make use of information provided in the form of graphs, diagrams, photographs and text. Candidates needed to utilise this information by making observations and using carefully selected data in support of their answers. In **Question 1(a)**, observant candidates gained full credit by using the image of the infected red blood cell in **Fig. 1.1** to describe the change in appearance of the cell.

When producing a written response to a question that asks for differences, the clearest answers identified the items that were being described. For example, in **Question 5(a)**, the strongest candidates started their descriptions by writing: 'The root can be a source because …' and 'The root can be a sink because …'.

General comments

There were many good scripts that were well-written and demonstrated sound subject knowledge and understanding. Some needed to consider the construction of their answers, which sometimes contained more than one idea and were written in a confused way so that clarity was lost. Many candidates wrote their answers as a list using bullet points and/or wrote in note form, with too much detail missing to be creditworthy. Those giving acceptable answers in bullet points gave concise ideas that included the necessary qualification to gain credit. Some candidates used abbreviations or used text language ('texting'), which is not appropriate for exam answers.

Candidates should take care using terms that have very similar spellings. For example, cytokinesis was often confused with cytokines in **Question 1(b)**. There was also confusion between terms. For example, the malarial pathogen was described as an antigen. The function of antibodies in **Question 1(c)** was also frequently confused. For example, candidates should know that antibodies are not cells so cannot secrete toxins, divide by mitosis or 'punch holes' in infected cells.

It is important that candidates take notice of the command words in the question. **Question 3(d)(i)** required candidates to use the graph shown in **Fig. 3.2** to describe the effect of an increase in the concentration of 2,3-DPG on the oxygen dissociation curve. Some needed to provide descriptions and instead gave explanations or interpretations, such as haemoglobin having a decreased affinity for oxygen, which was not required.

Several questions required candidates to think of explanations by using logic and syllabus knowledge. **Question 4(b)(ii)** was a good example of where candidates who took time to think through the information presented were able to produce high quality responses. Even if candidates had not considered why only one strand of DNA is transcribed, they could have applied their knowledge about base sequences in DNA and the genetic code to work out why only one strand is the template during transcription.

Comments on specific questions

Question 1

(a) Candidates who were able to gain full credit made reference to the change to the shape or outline of the red blood cell shown in **Fig. 1.1** and gave two further relevant suggestions as to how the presence of *P. falciparum* affects the cell. Some correctly stated that the cell no longer had a biconcave shape, or that the cell membrane had an irregular shape, or that the cell had enlarged. Many noted the idea that the cell is likely to burst, allowing the daughter cells visible in the transmission electron micrograph to escape to infect other red blood cells. Some suggested that haemoglobin would be used up by the parasite or that less oxygen would be carried by the cell owing to the loss of haemoglobin. There were some significant misunderstandings: some thought that the cell had become flaccid and/or plasmolysed and a few thought that the cell had become a sickle cell; others thought that *Plasmodium* stimulates cell division of the red blood cell. Some needed to realise that daughter cells fill the red blood cell and only referred to 'nuclei'. A number of candidates misread the question and described the transmission of *P. falciparum* or the part of the life cycle after entry of the infective stage (sporozoites) into the blood stream. Weaker responses wrote about *Plasmodium* as a bacterium or a virus, some including ideas about taking control of red blood cells and using the red blood cell ribosomes to make viral proteins.

(b) Good answers gave an outline of the stages that lead to the formation of daughter cells by referring to DNA replication, cellular growth and organelle formation, mitosis and cytokinesis. Some identified the question as asking about the asexual reproduction phase although a few suggested the parasite was dividing by meiosis rather than mitosis. Those who believed *P. falciparum* to be a bacterium wrote about the formation of peptidoglycan cell walls. It was clear from **Fig. 1.1** that binary fission does not occur. Many detailed all the stages of mitosis, which was not expected as the command word was 'outline'. A few noted the 'budding' of daughter cells visible in **Fig. 1.1**.

(c) Many candidates gave good explanations of the role of antibodies in reducing the spread of the malarial parasite in the bloodstream. Knowledgeable candidates stated that antibodies will bind to (non-self) antigens on the surface of the malarial parasite, so marking the parasite for destruction by phagocytes. Some of the stronger answers realised that this reduces the number of infective stages, so reducing the number that enter red blood cells or liver cells. A proportion of candidates showed a broader knowledge and wrote about agglutination, and a small number knew that the system was activated for killing the pathogen (complement activation). Candidates often wrote about other aspects of the immune system such as T-lymphocytes and cytokines, which did not gain credit. Misconceptions about antibodies included: stating that antibodies have receptors rather than antigen-binding sites, or describing antibodies binding to receptors, rather than antigens, on the surface of pathogens. Weak responses showed a lack of understanding that antibodies are large (glyco)protein molecules and so cellular actions were described, such as phagocytosis, the secretion of T-killer cells and formation of memory cells. Some thought that antibody production and the mode of action caused an immune response, rather than being part of an immune response.

(d) Candidates who had read the question carefully realised that they needed to discuss the factors that lead to the success of vaccination programmes in controlling, or even eradicating, a disease. Others, instead, described the factors that limit the success of vaccination programmes. Answers like this could only gain limited credit for identifying any of the factors that were considered to lead to a successful programme. A common factual error included the idea that vaccines contain antibodies, rather than antigens. Some candidates explained how vaccines have their effect and discussed memory cells and secondary responses to infections. These types of answer did not gain credit. A wide range of creditworthy points were made. A few candidates discussed the important ideas that the use of a 'live' vaccine and the use of contact tracing to make sure that those at most risk of a disease are vaccinated, were more likely to lead to the success of a vaccination programme.

Question 2

(a) (i) Answers to this question required two ideas. Many candidates stated that the concentration of amylose increases. Far fewer completed the explanation by giving the colour change that would occur in the presence of iodine solution. Some incorrectly stated that the enzyme reacts with the iodine solution to give the colour change. Many candidates needed to read and understand the

stem of the question above the graph, as they wrote about starch phosphorylase 'breaking down glucose 1-phosphate'.

(ii) Many candidates correctly predicted that absorbance would increase and become constant. There were different ways to state this, and many used the term plateau in their answer or simply stated that the absorbance reading would be constant at 1.80. A range of 1.79 to 1.81 was accepted. A number of candidates needed to be more accurate when extracting values from the graph. 'Absorbance will stop increasing' was ambiguous so was unable to gain credit. The expected explanation for this prediction was that all of the substrate was used up so that there was no glucose 1-phosphate left in the reaction mixture.

(iii) Many candidates simply stated that the colorimeter would give more accurate or more precise results. To improve, they needed to state that the results are quantitative rather than qualitative and not dependent on judgements made by eye. Those judgements would be made by comparing the colour of the iodine solution with a set of standards, which is very subjective and prone to error. There were few, if any, mentions of calibration and drawing graphs. Calibration graphs are useful because they allow the measurement of unknown concentrations by interpolation.

(b) There were some excellent accounts of the reaction catalysed by starch phosphorylase. The strongest responses were detailed and showed an understanding that it is the end of an amylose molecule that binds to the active site of starch phosphorylase, together with the glucose 1-phosphate molecule, so allowing a glucose residue to be added in the correct location. Many candidates mentioned the decrease in activation energy, the formation of a glycosidic bond and the formation of water. A few stated that at the end of the reaction, a phosphate ion leaves the active site of starch phosphorylase. Good answers described both substrates. Some could have been more precise in their answer, for example by stating that the substrates bind to the active site rather than bind to the enzyme. Some weaker responses included reference to iodine solution and colour changes, which was not necessary to answer the question.

Question 3

(a) (i) Many knew that the two different polypeptides were alpha globin and beta globin. The symbols for alpha and beta were allowed only if they were clear and unambiguous. Alpha polypeptide and beta polypeptide were not enough to gain credit. Common errors were: alpha glucose and beta glucose; alpha haemoglobin and beta haemoglobin; alpha helix and beta-pleated sheet; alpha glucose and beta glucose. Alpha and beta tubulin, the globular proteins that form microtubules, were seen occasionally.

(ii) Many candidates gave haem or haem group as the identity of **P** on the ribbon model of haemoglobin shown in **Fig. 3.1**. Incorrect answers included iron, Fe, Fe^{2+}, Fe^{3+}, peptide, secondary structure, oxygen, amino acid and beta-pleated sheet. Many wrote primary structure.

(iii) The majority gave the correct answer, primary structure. Some candidates qualified this by also stating that the sequence of amino acids in each of the polypeptides was not shown.

(b) Many candidates stated that carbon dioxide binds to haemoglobin to form carbaminohaemoglobin. Strong responses provided more detail and explained that a molecule of carbon dioxide reacts with the amine group at the end of each of the polypeptides in haemoglobin. A common error was to name carboxyhaemoglobin instead of carbaminohaemoglobin. Some remembered to mention dissociation of carbon dioxide in the lungs. A proportion of candidates needed to read the question more carefully to note that the answer concerned carbon dioxide that is not converted to carbonic acid.

(c) The question asked candidates to state the precise site where haemoglobin molecules bind with oxygen. Despite this, many candidates gave imprecise answers such as 'the lungs' or 'alveoli' rather than identifying the capillaries surrounding the alveoli.

(d) (i) Good answers stated that the oxygen dissociation curve shown in **Fig. 3.2** shifts to the right and that haemoglobin is less saturated at each partial pressure of oxygen. Many of these candidates gained full credit by using data taken from **Fig. 3.2**. A good number took the cue from the information provided and stated that the P_{50} is higher when the concentration of 2,3-DPG increases and used data from the graph to show this. Many candidates gave an explanation for the decrease

in saturation of haemoglobin in terms of the affinity of haemoglobin for oxygen and this gained no credit.

(ii) Many candidates deduced that the oxygen dissociation curve for the low concentration of 2,3-DPG showed that haemoglobin has a high affinity for oxygen and so would not donate its oxygen as readily as blood with a higher concentration of 2,3-DPG. Others incorrectly suggested that the higher saturation of haemoglobin shown in **Fig. 3.2** would mean that blood stored in a blood bank would provide more oxygen to the tissues of a person during an operation.

Question 4

(a) (i) Many candidates correctly gave RNA polymerase as the answer. The most common incorrect answer was DNA polymerase. Other incorrect answers included ligase, restriction enzyme, peptidyl transferase and helicase. 'Polymerase' without any qualification was also seen.

(ii) Phosphodiester bond was given on many scripts. Hydrogen bond was the most common error. Also seen were the other bonds found in biological molecules such as glycosidic, peptide and ester. 'Covalent' is never an acceptable answer in this context.

(b) (i) Candidates gave a variety of numbers including 4, 6, 15, 20 and 64. The primary transcript shown was 16 nucleotides long and this meant that only 5 amino acids would be coded for. Some candidates acknowledged the reference to only part of a strand being shown in **Fig. 4.1**, and statements such as 'five so far' were good answers.

(ii) There were some well-expressed answers that showed an understanding that only a template strand can be transcribed if a functional polypeptide is to be produced. The best of these used the term 'template strand'. Others gave more confused explanations of why only one of the two strands of DNA shown in **Fig. 4.1** is transcribed. The idea that the non-transcribed strand is the 'reference strand' was not accepted. Some understood that transcribing a nucleotide sequence, which is a complementary copy of the normally-transcribed strand, would mean that the primary transcript would code for a polypeptide with a different primary structure. The clarity of explanation was very varied. A number suggested that this would produce a non-functioning protein or a protein with a different function to the protein coded for by the *COL1A2* gene, which was credited. Using a similar concept, there were a few who explained that a different nucleotide sequence would be obtained because RNA polymerase would synthesise the primary transcript from the non-transcribed strand 'in the opposite direction'. Many went as far as stating it would code for a 'different polypeptide' and needed to mention a function. Some answers were confused with DNA replication where the enzyme had been identified as DNA polymerase. The answer here had nothing to do with the lagging strand and the Okazaki fragments that are formed during DNA replication. Some candidates had not read the information given in the question carefully enough as they stated that the sequence shown in **Fig. 4.1** could be part of an intron. The inclusion of the term 'exon' was there to exclude candidates from giving this answer.

(c) (i) Many confused the mitochondrion in the transmission electron micrograph (TEM) in **Fig. 4.2** with a cell and wrote about the cell surface membrane and cytoplasm. 'Cisternae' was a term fairly frequently seen, likely confused with 'cristae'. Ribosomes may just be visible in the TEM, but the circular DNA is not. Good answers included a double membrane, folded inner membranes or cristae, and the mitochondrial matrix.

(ii) Most candidates calculated the diameter of the mitochondrion as 0.6 μm. Some candidates used standard form for their calculation, sometimes ending up with numbers that included a 6 but to several orders of magnitude smaller or larger than the actual diameter of the mitochondrion.

(d) Most answers referred to active transport and facilitated diffusion, although they were not always accompanied by any further details. Endocytosis was seen occasionally, which is not correct. Many needed to pay closer attention to the question as they wrote about movement into cells and across cell membranes instead of the organelle concerned. In these instances, benefit was given to the candidate if the methods of transport across membranes were correct. It was a common error to state that facilitated diffusion needs ATP. Some answers incorrectly suggested that carrier proteins are involved in endocytosis.

Question 5

(a) (i) Good answers to this question included the terms 'source' and 'sink' so that the explanations were clear and credit could be awarded. Many explanations of the source were confused with the role of xylem and stated that water and mineral ions are absorbed by roots and provided to the rest of the plant. The question made it clear that it was about the transport of assimilates, which in this context are substances made by the plant, not substances absorbed by the roots from the environment. Some candidates thought that sucrose and other organic compounds required were absorbed from the soil. A few mentioned bidirectional transport in phloem. Some attempted to discuss direction of movement changing with changing seasons or life stages of the plant. Most answers revealed candidates need to improve their knowledge of why assimilates move to source or sink.

(ii) Sucrose and amino acids were the most common assimilates transported in the phloem given by candidates. Many other simple compounds travel in the phloem and other acceptable examples credited were named monosaccharides and disaccharides other than sucrose, and plant hormones. Examples of substances that were not accepted were cellulose, starch, hydrogen and water.

(b) There were many good answers to this question about the mechanism of translocation in phloem sieve tubes. Good answers began inside companion cells and explained that sucrose diffuses through plasmodesmata into sieve tubes and that this leads to a decrease in water potential so that water enters the sieve tube by osmosis. The role of the hydrostatic pressure gradient was explained, and the term mass flow used in the correct context. Some candidates gave only one or two of these ideas and wrote more about the movement of sucrose into the companion cell, which was not part of the answer required for this question. Common incorrect ideas included stating that sucrose moves from cell to cell by osmosis, or that sucrose diffuses within phloem sieve tubes.

(c) Candidates of all abilities were able to do well on this question if they paid careful attention to the details shown in **Fig. 5.1** and gave clear, concise statements that indicated comparisons between the three varieties of tobacco plants. Many responses noted that the increase in accumulation of TMV did not start until day 9 for variety **V1** and until day 22 for **V2**. They also used the graph to state that maximum accumulation was achieved on days 8, 25 and 36 or gave the period of time over which accumulation occurred in **V1** and **V2**. Some referred to the steepness of the three curves on **Fig. 5.1** and also spotted trends. Candidates often needed to notice that the arrow on **Fig. 5.1** showed the time when the plants were infected, and a number incorrectly stated that varieties **V1** and **V2** were infected later than time 0.

Question 6

(a) Many had the idea that the thicker walls of the ventricles contain muscle to generate the pressure required to pump blood a further distance. Fewer gave details that this was to the lungs in the pulmonary circulation, and that an even higher pressure is required to pump blood in the systemic circulation. Stronger responses gave the additional detail that a higher pressure is required to overcome the resistance provided by the blood vessels. Some thought the muscle in the ventricles is smooth muscle rather than cardiac muscle. Two very common statements seen that did not gain credit were 'ventricles have thick walls to withstand high pressure' and 'thick walls prevent bursting of the ventricles'.

(b) There were many fully correct identifications given in **Table 6.1**. Common errors included stating SAN and AVN rather than the full names of the two nodes in the first two rows of the table and misspelling 'atrioventricular' in rows 2 and 4. Bicuspid and mitral were accepted as alternatives for left atrioventricular valve.

BIOLOGY

Paper 9700/31
Advanced Practical Skills 31

Key messages

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

Candidates should be able to compare observable features of specimens of biological material, including differences between specimens in photomicrographs. When stating these differences, candidates should write about those features that were observable and also describe how the structure was different. For example, in **Fig. 2.3** the guard cells were positioned below the epidermis, while in **Fig. 2.4** the guard cells were positioned on the surface.

General comments

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

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

Comments on specific questions

Question 1

(a) (i) Some candidates correctly stated at least five temperatures to use for their investigation. The stronger responses stated temperatures that were evenly spaced out and included the unit, °C, in their answer.

(ii) The majority of candidates organised their results clearly by presenting a ruled table. The stronger candidates included the heading for temperature with units (°C) and the heading for number of bubbles. The majority of candidates gained credit for recording the number of bubbles for each temperature. Most candidates recorded the correct trend with the lowest number of bubbles at the lowest temperature and the highest number of bubbles at the highest temperature.

(iii) The majority of candidates stated that the number of bubbles was the dependent variable in the investigation.

(iv) The majority of candidates correctly stated that the final colour of the hydrogencarbonate indicator was yellow.

(v) Some respondents correctly suggested that one conclusion from their observation in **Question 1(a)(iv)** was that the carbon dioxide released had lowered the pH of the hydrogencarbonate indicator, causing it to turn yellow.

(vi) Some candidates correctly identified that a source of error was that the bubbles of gas given off were of different sizes and that an improvement would be to measure the volume of gas given off instead of counting the bubbles. Some candidates correctly suggested that a source of error was that the temperature of the yeast was not measured directly, and an improvement would be to place the thermometer into the test-tube containing the yeast.

(b) (i) Most responses correctly used the headings given in **Table 1.2** to label the *x*-axis (concentration of copper ions / parts per million) and the *y*-axis (mass of yeast / g). Some candidates labelled the incorrect axis or gave incomplete headings. The stronger responses used a scale of 0.2 to 2 cm for the *x*-axis and a scale of 4 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 error was not using the correct scale for the *y*-axis.

(ii) Many candidates used their graph to correctly estimate the concentration of copper ions that would result in a mass of 10.0 g of yeast cells and showed on the graph a line drawn from the *y*-axis to intercept the line of the graph.

(iii) A few candidates correctly suggested an explanation for the results shown in the graph and referred to non-competitive inhibitors binding to the allosteric site of the enzyme, resulting in distortion of the active site and fewer enzyme-substrate complexes being formed.

(iv) Many candidates correctly suggested why stainless steel was used instead of copper by noting that, unlike copper, stainless steel did not inhibit the enzyme and so did not reduce the growth of the yeast.

Question 2

(a) (i) Credit was awarded to candidates whose drawings did not include any cells and used most of the space provided. The stronger candidates gained credit for carefully following the instructions and drawing the region of the stem on **J1** indicated in **Fig. 2.1**. Many candidates gained credit for drawing at least two layers of tissue and the correct proportions of the vascular bundle. Stronger responses showed the subdivision of the vascular bundle and used a label line to correctly identify the vascular bundle.

(ii) Credit was awarded to candidates whose drawings were made using a sharp pencil to produce thin lines which joined up precisely and used most of the space provided. Many candidates were able to draw one large xylem vessel element and a group of three adjacent, smaller xylem vessel elements, with double lines representing the walls. The most common error was to draw lines that did not meet up precisely or were too thick. Most candidates used a label line to identify the wall of a vessel.

(b) (i) Most candidates stated that there were 3 whole stomata visible in **Fig. 2.2** and showed the calculation 2000 divided by 0.04. Many candidates then correctly multiplied by the number of stomata visible in the photomicrograph to estimate the total number of stomata on the leaf.

(ii) Many candidates correctly stated that one way to improve the accuracy of the estimate of the total number of stomata on the leaf was to repeat or sample more areas.

(iii) Some candidates recorded three correct observable differences between the leaf section in **Fig. 2.3** and the leaf section in **Fig. 2.4** in **Table 2.1**. For example in **Fig. 2.3** the guard cells are sunken whereas in Fig. 2.4 they are located on the surface.

(iv) Many candidates suggested that the environment where the plant in **Fig. 2.3** had grown was a dry environment.

BIOLOGY

Paper 9700/33
Advanced Practical Skills 33

Key messages

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

Candidates should be able to identify one main source of error in a particular investigation as any variable that may change during the recording of results, so making the results less accurate. When the candidates were carrying out the investigation, they should have observed that the yeast beads were of different sizes which would have affected the activity of the yeast cells and made the results less accurate.

General comments

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

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

Comments on specific questions

Question 1

(a) (i) Many candidates correctly stated that the temperature to use for the water-bath was at least 80 °C.

(ii) The majority of candidates organised their results clearly by presenting a ruled table. Stronger responses included the heading for the number of beads and the heading for time with units (seconds). The majority of candidates gained credit for recording a time for each of the sets of beads. Most candidates recorded the correct trend, a longer time for the test-tube with one bead and a shorter time for the test-tubes with more beads. The stronger candidates recorded the times in whole seconds.

(iii) The majority of candidates correctly stated that the number of beads was the independent variable in the investigation.

(iv) Many candidates correctly stated that a main source of error was that the beads were of different sizes or that the beads were not left in the sucrose solution for the same time.

(v) Some candidates correctly suggested that boiled yeast could be put in the beaker for the control experiment.

(vi) Many candidates correctly described how to modify the procedure to investigate the effect of changing the concentration of the sucrose solution on the rate of hydrolysis of sucrose by using a set number of beads and preparing at least five concentrations of sucrose. The higher-achieving candidates stated that they would use either proportional or serial dilution to make the concentrations of sucrose.

(b) (i) Most candidates correctly used the headings given in **Table 1.2** to label the *x*-axis (temperature / °C) and the *y*-axis (volume of fruit juice / cm^3). Some candidates labelled the incorrect

axis or gave incomplete headings. The stronger candidates used a scale of 20 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 error was not using the correct scale for the *y*-axis.

(ii) Many candidates used their graph to correctly estimate the volume of fruit juice extracted at 55 °C and showed on the graph a line drawn from the *x*-axis to intercept the line of the graph.

(iii) The majority of candidates correctly stated that from 30 °C to 60 °C the volume of fruit juice increased and after 60 °C the volume of fruit juice decreased. The most common error was not referring to the temperature.

(iv) A few candidates correctly suggested that because free pectinase can more easily come into contact with the apple pulp, more fruit juice was obtained between the temperatures of 30 °C and 50 °C than when using immobilised pectinase.

(v) A few candidates correctly suggested that an explanation for why more fruit juice was obtained when using immobilised pectinase between the temperatures of 60 °C and 70 °C than when using the free pectinase was that free pectinase denatures at a lower temperature. The stronger candidates also suggested that immobilised beads had a higher tolerance of higher temperatures.

Question 2

(a) (i) Credit was awarded to candidates whose drawings did not include any cells and used most of the space provided. The stronger candidates gained credit for carefully following the instructions and drawing the whole leaf on **K1**. Many candidates gained credit for drawing at least four layers of tissue and a minimal number of stomatal crypts on the underside of the leaf. The stronger candidates showed the subdivision of the vascular bundle and 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 epidermal cells with each cell touching at least one of the other cells, with double lines representing the walls. The most common error was to draw lines that did not meet up precisely or were too thick. The stronger candidates were credited for drawing the detailed shape of the epidermal cells. Most candidates used a label line to show the cell wall of an epidermal cell.

(b) Many candidates recorded their observable differences in an appropriate table. Many listed three correct observable differences such as the epidermal layer on **K1** was thinner than in **Fig. 2.1** or that there were trichomes present on **K1** and none in **Fig. 2.1** or that the xylem vessels on **K1** were smaller than in **Fig. 2.1**.

(c) (i) Most candidates accurately measured the line **P** and the line **Q** correctly and stated the appropriate units.

(ii) To calculate the percentage difference in length between vascular bundle **P** and vascular bundle **Q** many candidates correctly showed the length of **Q** minus the length of **P** divided by the length of **Q** multiplied by 100. Other methods were also acceptable. The stronger candidates recorded their answer to no more than two significant figures.

BIOLOGY

Paper 9700/34
Advanced Practical Skills 34

Key messages

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

The majority of candidates demonstrated that they could skilfully carry out an investigation and record the results in an appropriate table.

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

Candidates should be encouraged to observe fine detail when viewing slides under a microscope and include such detail when producing diagrams, such as the shape of the tissue layers and the section in plan diagrams and the shapes of epidermal cells in high power diagrams. Although leaves have the same common structures the fine detail of these structures may vary.

General comments

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

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

Comments on specific questions

Question 1

(a)(i) The majority of candidates used the words low, medium or high to correctly assess the risk of using **E**, **S** and **iodine**.

(ii) Most candidates selected three additional concentrations of amylase that were evenly spaced between the 2.0 and 0.4 percentage concentrations of amylase solutions stated in **Table 1.2**. Most candidates then went on to complete the table with the correct volumes of **E** and **W** to prepare the additional concentrations.

Some candidates only selected two additional concentrations and a few selected concentrations above 2.0 or below 0.4 percentage concentration. The most common error was to include incorrect volumes of **E** and **W** for the concentrations selected.

(iii) The majority of candidates organised their results clearly by presenting a ruled table and included the heading for percentage concentration of amylase and the heading for time including units (seconds). They gained credit for recording a time for all the concentrations of amylase made and recording results which showed that the time to reach the end-point for the lowest concentration of amylase was longer than the time to reach the end-point for the highest concentration of amylase. Some candidates recorded incorrect sampling times or times that exceeded 180 seconds and a few recorded colours at intervals of 15 seconds.

(iv) The majority of candidates correctly stated that the independent variable was the concentration of amylase.

(v) Many candidates demonstrated that they had carefully carried out the investigation and correctly recorded the time for **U**.

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

(vii) Most candidates correctly suggested one source of error in the procedure described in step 10 of the investigation as the difficulty in judging the colour for the end-point or that the end-point may have been reached between the 15 second sampling times. A few candidates stated that the size of the drop of amylase transferred by the glass rod varied.

(viii) Some candidates correctly suggested one improvement to reduce the source of error they stated in **Question 1(a)(vii)**. The majority of candidates who had suggested the difficulty in judging the colour for the end-point incorrectly suggested using a colorimeter rather than using a colour chart or colour standards to help identify the end-point. The majority of candidates who identified 15 seconds as too long between testing the amylase with iodine correctly suggested using times shorter than 15 seconds, and those candidates who had identified the transfer of different sized drops correctly suggested using a syringe to transfer a set volume of amylase to the iodine.

(ix) Most candidates correctly described how to modify the procedure to investigate the effect of pH on the time taken for amylase to hydrolyse starch. Many correctly suggested using five different pH values and keeping the concentration of amylase constant. Some candidates incorrectly suggested using five different pH concentrations or suggested using different acids and alkalis to change the pH.

(b) (i) The majority of candidates drew the graph using the headings given in the table to correctly label concentration of substrate / mol dm^{-3} on the *x*-axis and rate of reaction / arbitrary units (au) on the *y*-axis. Many candidates used scales of 0.2 mol dm^{-3} to 2 cm for the *x*-axis and 0.5 au to 2 cm for the *y*-axis and plotted the points exactly with a dot in a circle or a small cross. Many candidates drew a sharp, clear ruled line or a curve accurately connecting the points. The most common errors were using a non-linear scale on the *y*-axis so that the points could not be accurately plotted and drawing lines plot to plot that did not accurately connect the points.

(ii) Most candidates correctly used the graph to read off the value for the rate of reaction when the concentration of substrate is 0.45 mol dm^{-3}.

(iii) Many candidates correctly used the V_{max} of the enzyme and the graph to identify the inhibitor as a competitive inhibitor. The majority of candidates explained that as the substrate concentration was increased the same V_{max} as the enzyme without the inhibitor was reached. A few candidates explained that the inhibitor competes with the substrate for the active site of the enzyme and that the effect of the inhibitor is reversed by increasing the concentration of the substrate.

Question 2

(a) (i) Credit was awarded to candidates whose drawings did not include any cells and used most of the space provided. Most gained credit for carefully following the instructions and drawing the midrib of the leaf. The stronger candidates gained credit for drawing the tissue above the vascular bundle in the midrib and showing the correct shape and division of the vascular bundle. Most candidates used a label line to correctly identify the palisade tissue.

(ii) Credit was awarded to candidates whose drawings were made using a sharp pencil to produce thin continuous lines which joined up precisely and used most of the space provided. Most candidates were able to draw a line of four adjacent cells from the upper epidermis, with each cell touching at least one of the other cells and with double lines representing the cell walls. The strongest responses showed the different shapes of the cells observed. The majority of candidates used a label line to show the cell wall of one cell. The most common errors were to draw lines that did not meet up precisely and to draw a group of four cells rather than a line.

(b) The majority of candidates identified at least two observable differences between **Fig. 2.2** and **M1**. Most candidates stated that there were more vascular bundles present in **Fig. 2.2** than on **M1** and

that **Fig. 2.2** contained trichomes whereas **M1** did not. Some candidates stated that **Fig. 2.2** contained a bulge above the midrib whereas **M1** did not or that **Fig. 2.2** had a thicker cuticle than **M1**. Common errors were to include structures that were not observable, for example mitochondria, or to refer to the whole section as a cell.

(c) (i) Most candidates correctly showed the division of the length of one division on the stage micrometer by the number of eyepiece graticule units (40) present in one division of the stage micrometer. Many candidates correctly calculated the actual length of one eyepiece graticule unit and some showed how to calculate the actual length in micrometres.

(ii) Most candidates correctly measured the thickness of the midrib in **Fig. 2.4** using the eyepiece graticule placed across the figure and many candidates multiplied the number of eyepiece graticule units by the actual length of one eyepiece graticule unit, calculated in **Question 2(c)(i)**, to correctly calculate the actual thickness of the midrib in **Fig. 2.4**.

(iii) Many candidates correctly suggested a possible function of the structure labelled **A** in **Fig. 2.4**. Suitable examples included trapping water vapour, reducing transpiration and acting as a defence mechanism against predators by producing an insecticide. The most common incorrect answers included for water transport, water storage and absorption of water.

BIOLOGY

Paper 9700/35
Advanced Practical Skills 35

Key messages

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

Candidates demonstrated that they could follow instructions to skilfully carry out an investigation and record the results in an appropriate table. During the investigation, candidates were able to identify how the procedure could be improved so that a more accurate estimate of the concentration of sodium chloride in **U1** and **U2** could be obtained.

Candidates should be encouraged to think carefully about the investigation they have carried out and practise applying their knowledge about the topic when explaining their results.

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

General comments

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

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

Comments on specific questions

Question 1

(a) (i) Most candidates selected three additional concentrations of sodium chloride that were evenly spaced between 10 and 0 percent concentration of sodium chloride stated in **Table 1.2** and completed the table with the correct volumes of **S** and **W** to prepare the additional concentrations. Some candidates only selected two concentrations, or three concentrations between 10 and 5 percent or 5 and 0 percent, but gained credit for the correct volumes of **S** and **W** to prepare the stated concentrations.

(ii) The majority of candidates organised their results clearly by presenting a ruled table and included the heading for percentage concentration of sodium chloride and the heading for angle of bend and the units (degrees). They gained credit for recording an angle of bend for all the concentrations of sodium chloride made and recorded results which showed that the angle of bend for the lowest concentration of sodium chloride was smaller than the angle of bend for the highest concentration of sodium chloride.

(iii) The majority of candidates correctly stated that the independent variable was the concentration of sodium chloride.

(iv) The majority of candidates correctly recorded the angle of bend for **U2** as smaller than the angle of bend for **U1**.

(v) Many candidates used their results from **Question 1(a)(ii)** and **Question 1(a)(iv)** to correctly estimate the concentration of sodium chloride in **U1** and **U2**.

(vi) A few candidates correctly compared the movement of water between the potato tissue placed in **U1** and the potato tissue placed in **U2**. They correctly explained that **U1** had a lower water potential than **U2** and so more water moved out of the potato tissue placed in **U1** by osmosis than from the potato tissue placed in **U2**. Some candidates explained that **U1** had a lower water potential than **U2** and many candidates gained credit for explaining that the movement of water was due to osmosis. Many candidates incorrectly referred to the concentration of sodium chloride in **U1** and **U2** instead of referring to water potential, or they referred to the potato tissue as **U1** and **U2** and explained that the potato tissue had different concentrations of sodium chloride. The most common mistake was to compare the difference in the angle of bend between the potato tissue placed in **U1** and the potato tissue placed in **U2** and explain that this was because water moved out of the potato tissue placed in **U1** and into the potato tissue placed in **U2**.

(vii) The majority of candidates suggested at least two improvements to the procedure so that a more accurate estimate of the concentration of sodium chloride in **U1** and **U2** could be obtained. Most candidates correctly described using concentrations with narrower intervals with the stronger candidates stating concentrations around the estimate for **U1** and **U2**. Many candidates suggested repeating the whole experiment and calculating a mean or testing each piece of potato tissue separately. Other suitable answers included using potato tissue with the same dimensions, measuring the mass of the potato tissue and calculating the percentage change in mass, and applying the same force or tension when bending the potato piece.

(b) (i) The majority of candidates used the headings given in the table to correctly label the *x*-axis (type of vegetable extract) and the *y*-axis (concentration of sodium chloride / mg 100 cm^{-3}). The majority of candidates also labelled each bar clearly and drew bars of equal width on the *x*-axis. They used a scale of 20 mg 100 cm^{-3} to 2 cm for the *y*-axis and plotted each bar accurately. Many candidates drew ruled lines for the bars so that the vertical lines joined with the horizontal lines precisely. The most common error was drawing bars that were joined and not separate.

(b) (ii) Most of the candidates correctly suggested celery as the vegetable which resulted in no plasmolysed cells.

Question 2

(a) (i) Credit was awarded to candidates whose drawings did not include any cells and used most of the space provided. Most of the 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 a wavy outline for the epidermis and at least one subdivided vascular bundle. The majority of 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 continuous lines, with no shading, which joined up precisely and used most of the space provided. Many candidates gained credit for carefully following the instructions to draw a group of one large and three small adjacent xylem vessel elements, with double lines representing the xylem vessel element walls. The stronger candidates drew one large oval xylem vessel element and three small xylem vessel elements with different shapes. Many candidates used a label line to identify the wall of one xylem vessel element. The most common errors were drawing lines that did not meet up precisely and drawing four circles the same size for all of the xylem vessel elements.

(b) The majority of candidates identified at least two observable differences between **Fig. 2.2** and **L1**. Most candidates stated that there were more vascular bundles present in **Fig. 2.2** than on **L1** and that **Fig. 2.2** contained smaller vascular bundles than **L1**. Some candidates stated that **Fig. 2.2** contained a large central region whereas **M1** had a small central region or that the outline of **Fig. 2.2** was round and **L1** was wavy. Common errors were to include structures that were not observable, for example mitochondria, or to refer to the whole section as a cell.

(c) (i) The majority of candidates correctly measured the diameter of the whole stem section and the diameter of the central region in **Fig. 2.2** using the line **X–Y** placed across the figure. The measurements were recorded using appropriate units.

(ii) Many candidates correctly showed the division of the diameter of the whole stem section by two and the division of the diameter of the central region by two to calculate the radius. Many candidates correctly used the formula to calculate the area of the whole stem section and the area of the central region and gave appropriate units.

(ii) Some candidates correctly showed the ratio of the area of the whole stem section to the area of the central region. Many candidates incorrectly divided the area of the whole stem section by the area of the central region and showed this answer.

BIOLOGY

Paper 9700/36
Advanced Practical Skills 36

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 compare observable features of specimens of biological material, including similarities between specimens on a microscope slide and specimens in photomicrographs. When stating these similarities, candidates should write about those features that were observable and also describe how the structures were similar, such as on the section **N1** and the section in **Fig. 2.2** there were both large and small vascular bundles present.

General comments

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

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

Comments on specific questions

Question 1

(a) (i) Many candidates were able to carry out a serial dilution, showing the correct concentration below each beaker (1.0 mol dm^{-3}, 0.50 mol dm^{-3}, 0.25 mol dm^{-3} and 0.125 mol dm^{-3}) and transferring 5 cm^3 of the previous concentration to the next beaker and adding 5 cm^3 of distilled water to each beaker.

(ii) The majority of candidates correctly completed **Fig. 1.2** by drawing four small circles to show where the wells should be positioned in the agar. The stronger candidates labelled five circles with the concentrations of hydrochloric acid prepared in step 1.

(iii) The majority of candidates organised their results clearly by presenting a ruled table. The stronger candidates included the heading for the concentration of hydrochloric acid / mol dm^{-3} and the heading for distance with units (mm). The majority of candidates gained credit for recording a distance for each of the stated concentrations of hydrochloric acid for both Petri dishes, **A** and **B**. Most candidates recorded the correct trend, a greater distance for the highest concentration of hydrochloric acid and a shorter distance for the lowest concentration of hydrochloric acid. The stronger candidates recorded the distances in whole millimetres.

(iv) Many candidates correctly calculated the rate of diffusion for 2.0 mol dm^{-3} hydrochloric acid by dividing the diffusion distance by 20 minutes and showed their working. The stronger candidates used the appropriate units, mm / minute.

(v) Some candidates correctly suggested how to modify the procedure to investigate the change in the rate of diffusion by stating that they would use one concentration of hydrochloric acid and measure the diffusion distance every 5 minutes for 25 minutes. The higher-achieving candidates then went on to say that they would calculate the rate of diffusion for each of the 5-minute intervals to show the change in the rate of diffusion.

(b) (i) Most candidates correctly used the headings given in **Table 1.2** to label the *x*-axis (percentage concentration of alanine) and the *y*-axis (rate of absorption / $\mu m\, h^{-1}$). Some candidates labelled the incorrect axis or gave incomplete headings. The stronger candidates used a scale of 20 to 2 cm for the *x*-axis and a scale of 500 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 error was not using the correct scale for the *y*-axis.

(ii) Some candidates correctly explained the shape of the graph by stating that the higher the concentration of alanine the higher the rate of absorption. The stronger candidates explained the role of co-transport proteins (carrier molecules) within the cell surface membrane to absorb the amino acids, and that at 50 to 70 per cent concentration of alanine the carrier proteins were the limiting factor.

Question 2

(a) (i) Credit was awarded to candidates whose drawings did not include any cells and used most of the space provided. The stronger candidates gained credit for carefully following the instructions and drawing the region of the stem on **N1** indicated in **Fig. 2.1**. Many candidates gained credit for drawing at least three layers of tissue and the tissues present in the corner of the stem. The stronger candidates showed the precise shape of the vascular bundle and 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 xylem vessel element touching at least one of the others, with double lines representing the walls. The most common error was to draw lines that did not meet up precisely or were too thick. The higher-performing candidates were credited for drawing the detailed shape of the xylem vessel elements. Most candidates used a label line to identify the lumen.

(b) Many candidates recorded three correct observable structures that were similar on the section on **N1** and the section in **Fig. 2.2**.

(c) (i) Most candidates accurately measured the width of the whole section, **P**–**Q**, and the width of the middle layer and stated the appropriate units. The stronger candidates showed the measurement of the middle layer divided by the length of **P**–**Q** multiplied by 100 and gave the answer to two significant figures.

(ii) The majority of candidates correctly stated that to determine the mean width of the middle layer of the stem section, multiple measurements should be taken around the stem at different positions. These measurements should then be added together and divided by the number of measurements taken.

BIOLOGY

Paper 9700/41
A Level Structured Questions

Key messages

To achieve highly in this paper, candidates need to be prepared to mentally process information and data and generate novel ideas. Candidates need to go further than memorising lists of ideas linked to syllabus learning outcomes in order to access the highest grades, since half the marks available are for questions designed to test the handling, applying and evaluating of information (AO2 skills).

General comments

The highest-performing candidates made intelligent use of the information in the question, particularly when directed to use data to draw conclusions. **Fig. 1.1** was the important reference point for all parts of **Question 1**. Some other questions that required candidates to show they had used the data provided were **Question 2(d)(iii)**, **Question 3(c)(i)**, **Question 3(d)(i)**, **Question 4(b)** and **Question 6(a)(iii)**. Weaker candidates sometimes attempted to answer these questions using memorised information only and needed to use or refer to the diagrams or data to gain credit.

A significant proportion of candidates omitted **Question 8(a)**, where the answer had to be added to a graph and was not prompted by the presence of a dotted line answer space. It is essential that candidates read all of the information provided to help them.

The main areas of knowledge candidates can improve on are being able to distinguish between the thylakoid membrane and the thylakoid space and understanding that the guard cell and the stoma are different things. Candidates also need to have a more realistic view of somatic gene therapy, understanding its technical challenges.

Comments on specific questions

Question 1

Candidates interpreted a schematic diagram of the processes occurring in a chloroplast.

(a) (i) Most correctly identified the individual components of the granum as thylakoids. Wrong answers included granum and granules.

(ii) Stronger answers clearly listed structural features and linked each feature to its functional role. The strongest answers stated that the thylakoid membrane is the site where the pigments, photosystems, electron carrier proteins or ATP synthase are found, and explained that it is the thylakoid membrane that carries out the related roles of photophosphorylation, chemiosmosis and ATP synthesis, while the lumen is where hydrogen ions accumulate. Most commonly, credit was gained for commenting on the large surface area of the stacked thylakoids and relating this to the function of increasing light absorption. Weaker candidates wrote freely about what they recalled about a granum and needed to obey the question rubric to link the structure or appearance of individual features of the granum and thylakoids to the function of each aspect. One major source of error for candidates was not differentiating between the thylakoid membrane and the thylakoid lumen. It was not acceptable to state ‘thylakoids contain pigments’.

(b) (i) Most candidates correctly identified the metabolic cycle **C** in the chloroplast stroma as the Calvin cycle. Wrong answers included Krebs cycle and carbon dioxide fixation cycle.

(ii) The most successful descriptions of why **C** is described as a cycle referred to the regeneration of RuBP using five sixths of the TP available.

(c) (i) Product **B** was made from water in the granum and moved out of the chloroplast, and around half of candidates identified this as oxygen. Many who did not deduce this named ATP instead. The products of the light dependent reaction (ATP and reduced NADP) do not leave the chloroplast as was shown in **Fig. 1.1** to be the case for product **B**, and instead are used in cycle **C** in the stroma.

Product **D** from the Calvin cycle could be correctly named as triose phosphate, glucose or a later metabolite such as starch, glycerol, amino acids or fatty acids. Calvin cycle intermediates like GP were not correct, nor were light dependent reaction products like reduced NADP and ATP which some candidates gave as answers for **D**.

(ii) Many candidates correctly linked oxygen to aerobic respiration and glucose to being a source of food or energy. A minority of candidates made the error of referring to 'energy production' rather than energy release or provision from respiration of glucose. A few candidates also incorrectly stated that glucose releases energy 'for respiration' instead of by respiration. Candidates need to comment on the ecosystem aspect to the question and only a few realised glucose and its products are important in energy transfer in food chains and webs.

Question 2

This question explored the genetic variation level of biodiversity and its potential impact on the conservation of species diversity.

(a) Many candidates named the ecosystem level of biodiversity and the stronger candidates fully described the species level as including both the number of species and their relative abundance.

(b) Strong answers used the question information to explain that a database can store many DNA sequences so they can be accessed online and that computer algorithms can compare sequences and process large quantities of data quickly. Many answers listed general remembered points about bioinformatics and needed to address the demands of this specific question to gain the credit available.

(c) (i) Most candidates realised that *Anopheles* had most genetic variation; some needed to give the genus name alone as requested.

(ii) Many candidates identified that three kingdoms were represented in the table. The commonest wrong answer was two.

(d) (i) Candidates found it difficult to express why low genetic variation is potentially a problem for species survival. Some misinterpreted the word species and needed to realise this question was exploring the potential for species extinction.

Strong answers explained that genetic variation is necessary for selection to act on and that the species with low genetic variation will be less able to adapt to change. Some correctly argued that with genetic uniformity, a single disease or selection pressure could eliminate many members of a population or species at once. Stronger answers worked from the basis of the correct idea of low genetic variation as a small number of alleles existing in the population at a gene locus, perhaps just one. Weak answers often described an incorrect idea of low genetic variation as an allele having a low frequency in a population. The frequencies of the different alleles at a gene locus must add up to 100% so if one allele is at a low frequency one or more others must be at high frequency. The relative frequencies depend on selection pressures acting for or against certain alleles.

Arguments that stated the possibility of harmful recessive alleles coming together confused low genetic variation within the gene pool with inbreeding. Some wrong answers stated that 'low genetic variation causes inbreeding depression' whereas in fact the argument should be the other way round, that repeated inbreeding can reduce genetic variation. Very weak answers sought to explain how low genetic variation arises instead of explaining how it impacts on species survival as required by the question.

(ii) Most answers described the inverse correlation between genetic variation and conservation status or risk of extinction in an intelligible way, such as 'the lower the genetic variation the higher the conservation status' or 'as genetic variation increases the risk of extinction decreases'.

(iii) This question required skills of data analysis to evaluate a prediction. Often candidates had trouble highlighting the species that most obviously showed the prediction to be incorrect. Candidates tended to pick data randomly without selecting the examples which best illustrated the point they were trying to make. Vague answers that described one animal as having more variation than another animal but being more endangered did not gain credit**.** The major pieces of data that conflicted with the prediction were species with the highest and lowest levels of genetic variation not having low and high conservation status respectively, e.g. minke whale with the lowest variation being of low status, least concern, and chimpanzee with the highest variation being of high status, endangered. Some candidates correctly identified a pair of species with the same level of genetic variation and explained that they had different status, such as the whale as least concern and the lion as vulnerable. A few weaker answers did not refer to the data in **Fig. 2.2** at all, instead providing other items of recall to attempt to answer the question.

Question 3

The Hardy-Weinberg principle, continuous variation, plant hormones and graph analysis were tested in this question.

(a) Many candidates successfully calculated the number of heterozygous plants using the Hardy-Weinberg principle to reach the answer of 511. The commonest error in working that meant candidates arrived at a wrong answer but gained some credit for subsequent correct processing was giving *q* as 0.4 instead of the square root of 0.4. Another frequent error was using a calculated figure of *pq* instead of *2pq* to find the number of heterozygous plants. A few candidates tried to start by finding the proportion of plants showing the dominant purple phenotype in the population, instead of the recessive phenotype where all the red-flowered plants are homozygous recessive and so equal to the single term q^2.

(b) Most candidates used the information given to suggest that the flower colour showed continuous variation within the population due to its control by several genes, the influence on colour of the environment and the inability to divide the colours into discrete classes since they formed a gradual range. The weakest answers described individual flowers changing colour rather than the range of phenotypes in the population as a whole.

(c) (i) Candidates did relatively well with this question, using **Fig. 3.2** to explain that an increase in carbon dioxide concentration causes stomatal aperture size to decrease, and that this will lead to less water loss through stomata.

(ii) Strong candidates wrote full, correct answers to this AO1 (knowledge and understanding) question requiring recall of how abscisic acid causes the closure of stomata. Candidates needed to be able to distinguish between a guard cell and a stoma to gain credit. The details provided only gained credit with clear correct reference to either the pair of cells surrounding the stoma or the aperture or pore itself.

(d) (i) Most candidates gave some correct description of the results shown in **Fig. 3.3**. The strongest answers made general comments about the overall patterns and then supported these with figures stating day and units. Some candidates described patterns in the data over the time period without comparing between the different treatments.

(ii) Many candidates knew that when auxin binds to its receptors hydrogen ions are pumped into the cell wall, resulting in disruption of links between cellulose microfibrils in the wall.

Question 4

The question context was potato plants that were genetically modified to express proteins toxic to insects.

(a) (i) Strong candidates had no problem defining recombinant DNA and giving some detail of the technology that produces this, e.g. joining a gene to a vector to produce DNA that originates from two sources. Weak answers wrote about placing genes in a nucleus, cell or body with no suggestion that one piece of DNA has become physically joined to another. Others described one

'strand' of DNA joining to another, which implies the annealing of two strands to make a double helix, not the correct idea of ligase sealing the nicks in both sugar-phosphate backbones to join two linear stretches of DNA.

(ii) Most candidates scored for suggesting that the purpose of creating two different types of GM potato plants was to compare the effectiveness of each or to see which one worked best in killing insects.

(iii) The test on non-GM potato plants was correctly explained by most candidates as being a control experiment. Some candidates negated their answer by stating 'as a control variable'.

(b) Candidates were asked to use the data in **Table 4.1**. Analysis of the table led to a few strong answers explaining that both GM varieties **A** and **B** killed insect larvae, that growing GM potatoes will increase the yield of potatoes, and that this is particularly the case if **A** is grown since it produced the best results. The majority of answers covered only one or two of these points. Many answers seen needed to refer to **A** or **B**, and mention GM. The weakest responses made no mention of the question context or results table and listed benefits of GM such as reduced insecticide application from memory.

Question 5

Candidates analysed data relating to RQ and compared respiration in anaerobic conditions in mammals and yeast.

(a) Many candidates correctly selected malic acid as the respiratory substrate with the highest RQ and oleic acid as the respiratory substrate with the lowest RQ.

(b) Responses that scored most highly showed both knowledge and clear organisation, making clear which points were similarities shared by both types of organism, and which were differences, such as fermentation in mammals producing lactic acid and fermentation in yeast producing ethanol. Common errors were writing lactose or lactase instead of lactic acid (or lactate); stating that pyruvate is produced or just 'involved' rather than used in fermentation; and confusing reduced NAD, which is used in both types of fermentation, with oxidised NAD, which is regenerated in both types of fermentation. Few candidates noted that both types of respiration occur in the cytoplasm (some candidates thought the processes occurred in mitochondria). Some candidates thought that carbon dioxide is released in both processes, not just in yeast fermentation. Candidates often needed to improve on their descriptions of what is being oxidised and what is being reduced. Some answers discussed events that occur in glycolysis despite the question being limited to a description of fermentation only.

Question 6

Candidates interpreted the F2 results of a genetic cross involving a new mutation in tiger barbs.

(a) (i) A few candidates realised that as the transparent phenotype reappeared in the F2 generation, then it must be genetic or inherited. Some pointed out that the mutation had caused a new allele to form, or that the transparent phenotype is caused by a recessive allele. Many candidates struggled to express any pertinent ideas.

(ii) This question was done well with most candidates deriving the 9:3:3:1 ratio from the results in **Table 6.1**.

(iii) Most responses gained credit for stating that white stripes and transparent are recessive characteristics. Candidates who made a deeper analysis realised that two separate genes were involved, one for stripes (black or white) and a second gene for the body colour (gold or transparent). There was confusion about the meaning of a 9:3:3:1 ratio, with many candidates thinking this was evidence of linkage, whereas in fact it shows that the two genes assorted independently on separate autosomes. A few answers included the fact that this was a dihybrid cross.

(b) The main correct point made by candidates was to state that independent assortment happened in metaphase I. A very few candidates attempted to use symbols to explain how the two pairs of chromosomes, each with a dominant and recessive allele, could line up in two different ways giving

four possible gametes and hence the ratio of phenotypes seen in **Table 6.1**. The majority of candidates needed to explain the processes occurring in meiosis in the F1 fish that allowed the variation in the F2 fish shown in **Table 6.1** to arise as required by the question. Instead of focusing on how the wild-type heterozygous F1 fish produced the four classes of phenotypes in the table, most candidates reproduced a general answer from memory about how meiosis generates variation. Most candidates stated crossing-over would occur, although the 9:3:3:1 ratio shows that the two genes assorted independently and must be on separate chromosomes, making crossing-over irrelevant and in no way responsible for the combinations of traits seen in the F2 offspring.

Question 7

The three parts of this question related to muscle.

(a) (i) The commonest correct points made were mentioning the synaptic cleft and receptors. Some candidates gave one or two similarities in the distribution or function of ion channels in both, and some named the presynaptic and postsynaptic membranes (or sarcolemma). A small number of candidates knew that both have vesicles containing the neurotransmitter acetylcholine, and a very few mentioned large numbers of mitochondria. Few candidates were able to give four structural similarities shown by a neuromuscular junction and a cholinergic synapse to gain full credit. Some candidates spent time describing processes when the focus of the question was on comparing structural features.

(ii) This was an unusual question context, and many candidates applied their knowledge of the sliding filament theory to reason a correct answer. Clarity of language was important, as to gain credit the answer had to make clear that few calcium ions would bind to troponin, not many troponin molecules would change shape, the movement of tropomyosin would be less (than if calcium phosphate did not form) or little, and so on, stressing the reduced occurrence of each stage of the process. A few candidates considered the question from the angle of less phosphate being available to make ATP so less cross-bridges would break, and these answers also gained credit.

(b) Most candidates identified **A** in **Fig. 7.1** as adenyl cyclase; a smaller number gave the full name of **B** as protein kinase A.

Question 8

This question explored how light intensity affects plant physiology and gene expression.

(a) This question was commonly omitted by candidates as there was no dotted line for them to show their answer. This demonstrates the need for candidates to read all parts of the question paper carefully. Some candidates knew the area of the graph where light intensity acted as a limiting factor on the rate of photosynthesis and needed to place their **X** on the curve to gain credit.

(b) (i) Many candidates named reverse transcriptase as the enzyme that produces cDNA from an mRNA template. Wrong answers included DNA polymerase, RNA polymerase and RNA transcriptase.

(ii) The types of proteins that control gene expression in plants were most often named correctly as transcription factors, though some candidates focused on the plant context and were more specific, naming PIF, or gave the name of a sub-group of transcription factors like repressors.

(iii) Many candidates stated that in high light intensity the rate of photosynthesis is increased, and a small proportion went on to reason that because of this, plants would need to make more proteins and enzymes to be used in photosynthesis, such as rubisco and electron carrier proteins. Most candidates suggested that with more photosynthesis occurring there would just be more energy for the plant to switch on extra genes.

Question 9

The evolution and physiology of green lacewings formed the context for this question.

(a) (i) Most descriptions of how the tympanal organ of green lacewings could have evolved by natural selection gained some credit. The most frequently seen points were that the selection pressure is bats, and that lacewings with tympanal organs or that can detect high frequency sounds survive and reproduce. Many candidates needed to show understanding of the word ‘random’ and

contradicted their argument by stating ‘random mutation occurs so that tympanal organs develop’ or ‘random mutation occurs because lacewings need to escape from predators’. Any idea that the genetic change is due to a selection pressure or occurs as a result of a need negated the idea of randomness. The term ‘allele frequency’ needs to be better understood by candidates who suggested that ‘better-adapted lacewings have increased allele frequencies’ or ‘over time the allele frequency changes whereby individuals with the allele dominate those who do not have the allele’.

(ii) Careful respondents noted that the first event in the sequence took place in the receptor cell and that they needed to describe the sequence of events that would lead to an action potential in a separate cell, the sensory neurone. Weaker answers needed to make clear which of the two cells, receptor cell or sensory neurone, was being discussed and many candidates needed to realise that communication between two separate cells in the nervous system involved a synapse. In answers that attempted to describe what happens at a synapse between a receptor cell and a sensory neurone, some common errors appeared. One was writing that vesicles are released by exocytosis, or that vesicles bind to receptors on the post-synaptic membrane. Another was to confuse the neurone and the membrane, with answers wrongly stating that ions move ‘into the membrane’ instead of into the neurone. Some candidates lost credit for omitting to state ‘ions’ for components such as calcium ions and sodium ions, or for referring to them with incorrect symbols.

(b) Strong answers named sympatric speciation and referred to a behavioural difference giving rise to reproductive isolation. Some candidates wrote allopatric, and descriptions often did not match with the question information about the ranges of the two species overlapping in the modern day. Some candidates needed to name a form of speciation but still made a limited range of salient points.

Question 10

Candidates were often most successful at gaining credit for naming diseases for which genetic screening can be done, and elaborating on actions people might take if a test proves positive. Some candidates were able to describe how insulin can be produced in recombinant bacteria. Many candidates struggled to recall and organise knowledge about genetic technology to outline how it can be applied to medicine. Wording needed to be specific when candidates attempted to write about gene therapy. Answers often needed to consider which human cells should or could receive a normal allele and many candidates had an unrealistic view of the limitations of this approach, assuming that gene editing meant that all or any cells could simply be edited within a human body or even an unborn foetus. In general, answers showed difficulty moving from the concepts of altering DNA at the molecular level, to the whole organism physiological level, and the challenges of introducing new DNA to selected accessible cells.

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Paper 9700/42
A Level Structured Questions 42

Key messages

- Candidates should take notice of the command word in each question. For example, 'describe' means that they should state the main points, whereas 'explain' requires reasons to be given, and 'suggest' requires further application of knowledge.
- Candidates should always look at the number of marks allocated to a question which acts as a guide to indicate the number of separate points that may need to be made. Those who make one good point and then use the space to expand upon this same point will often gain no further credit.

General comments

There was a good range of marks awarded on this paper and it was found to be accessible to candidates of all abilities. Candidates found **Questions 2**, **4** and **5** more difficult.

Comments on specific questions

Question 1

(a) The majority of candidates were able to identify at least two of the substances in **Fig. 1.1** correctly. Most recognised that **A** was carbon dioxide and **D** was ethanal, although a common mistake was to confuse reduced NAD with NADH for substances **B** and **C**, or refer to ATP/ADP.

(b) There were many good explanations as to how anaerobic pathways allow cells to function in the absence of oxygen, with more able candidates stating that the reduction of pyruvate or ethanal by reduced NAD would regenerate NAD so glycolysis could continue and still produce ATP. A few candidates commented that ATP would be produced by substrate-linked phosphorylation. Candidates needed to mention that reduced NAD would be re-oxidised and, while some appreciated that a little ATP would be made, its production was occasionally incorrectly linked to the metabolism of pyruvate.

(c) The adaptations of rice plants which allow them to grow in flooded fields were generally well described by candidates and some were able to explain them. The presence of aerenchyma tissue facilitating the delivery of oxygen to submerged parts of the plant was not always linked to aerobic respiration. While many recognised that rice plants could rapidly grow tall, often detailing the mechanisms involved, they needed to go on to state that this would result in the leaves being above the surface of the water and exposed to air. However, many understood that anaerobic respiration, or ethanol fermentation, was possible due to the cells' high ethanol tolerance or high concentration of ethanol dehydrogenase. References to submerged leaves having corrugated surfaces to trap air were rarely seen.

Question 2

(a) Candidates were asked to interpret a novel diagram, **Fig. 2.1**, which showed the life cycle of yeast and its alternating generations. This showed that yeast could carry out both asexual reproduction by mitosis and sexual reproduction by meiosis. The diagram also indicated whether the cell was haploid or diploid. Candidates were asked to identify stages that involve mitosis. Many candidates were not familiar with haploid individuals existing on their own. Both stage **1** and stage **3** show that mitosis has occurred, one as a haploid cycle and one as a diploid cycle. Candidates were also

asked to identify the stage that involves meiosis, leading to a reduction from the diploid number to the haploid number, stage **4**; this was the part that was most commonly answered incorrectly. Candidates needed to remember that meiosis and random fusion of gametes causes genetic variation and go on to identify either stage **4** or stage **2**. Stages showing only haploid cells would need to be either stage **1** or stage **5** where each cell clearly had only one letter: **a** or **α**. Cells showing only diploid cells could only be stage **3** where each cell had two letters **a** and **α**.

Overall, candidates need to improve their understanding in this topic area.

(b) This question asked specifically about the type of reproduction that made spores in stage **4**, so that had to be sexual reproduction and thus involve meiosis. Candidates were asked to suggest and explain the advantage of meiosis in a changing environment. Good responses were able to access most of the credit by explaining that meiosis causes genetic variation by independent assortment and crossing over, and that following meiosis there would be random fusion of gametes to generate more genetic variation. Some understood that the question was asking about meiosis and referred to genetic variation and needed to add further detail of crossing over or independent assortment as reasons for this. Many frequently discussed adaptation or survivability and did so in the context of the whole species rather than some individuals being adapted or surviving. Some candidates referred to dormancy without mentioning advantageous combinations of alleles or other stages in the life cycle.

(c) Candidates were told that a new harmful recessive mutation had occurred but that it did not have a damaging effect on the population of cells, whether asexually reproducing haploid cells or asexually reproducing diploid cells.

There was a misconception amongst candidates that haploid individuals exist, and that they only have one copy of each chromosome and hence each gene, so that if a cell had a harmful recessive mutation, then that cell would be affected and likely die. Many candidates were not confident about the population context given; that if the affected cell dies then the rest of the asexually reproducing cells in the population would be unaffected and thus survive. Also, that the advantage of being haploid is that the individual with the harmful recessive mutation is removed from the population and so this protects the population. A very small number of candidates achieved full credit for the haploid context.

The most common response seen was for the asexually reproducing diploid cells and that the dominant allele, which would be normal, would mask the recessive allele. Many candidates explained that the cell needed to be homozygous recessive for the mutation to show its effects and needed to go on to say that a dominant allele would mask it or that it would not be expressed in the heterozygous state.

(d) This question about features of members of the Kingdom Fungi was answered well. Although some candidates believed Fungi to be prokaryotic, the majority could give two features; most commonly being heterotrophic and having a cell wall made of chitin.

A few candidates gave statements about the feeding type and, instead of heterotrophic or saprotrophic, gave a more general response of a decomposer which would include detritivores and scavengers, and not the feeding type of individuals from Kingdom Fungi.

Question 3

(a) This question was about selective breeding in wheat and proved to be more difficult to answer than previous questions on selective breeding in cattle.

With the command word ‘Outline’, only the main steps were required:
1 Select the plants with disease resistance.
2 Breed these plants.
3 Plant seeds to grow the offspring.
4 Select offspring with resistance and breed.
5 Repeat this process over many generations.

Many candidates were able to achieve most of the credit available, with a few attaining full credit.

A common error was to select varieties of wheat rather than individual plants with disease resistance, and often one of the parents was said to have a desired characteristic other than disease resistance, which was not relevant to this question. Many candidates missed out on credit for omitting to repeat for many generations. Some candidates confused selective breeding with genetic engineering and gave details of inserting resistant genes. This often meant no credit could be awarded.

(b) Many candidates were able to answer this question and there were a lot of ways in which to achieve full credit. Most candidates suggested genetic variation, less hybrid vigour or inbreeding depression. Some also elaborated with explanations of harmful recessive alleles coming together and susceptibility to environmental change.

Question 4

(a) A significant number of candidates showed a very good understanding of the use of marker genes and were able to gain most of the credit available on this question. A small number added extra information, most commonly that the fluorescent proteins are not harmful. Some confused the techniques of marker genes with the use of microarrays asked for in **Question 4(c)(ii)**, which often enabled them to only gain credit for the use of UV light.

Few candidates appreciated that the gene of interest and the marker gene are both transcribed and so both their coded proteins are produced. Also, that the fluorescence is due to a protein which shows under UV light. Many candidates described the marker gene as if it was a fluorescent tag itself so confused it with a fluorescent marker. There were many incorrect references to genes fluorescing. Very few mentioned that they use the same promoter.

(b) Many were able to gain full credit. Most candidates had the right idea that herbicide resistance allowed for the use of herbicides which reduced competition and allowed for increased yield.

The most common error was that the resistance to the herbicide would mean no herbicide was needed and that this would save money not buying herbicides. Other errors included the effect of pests, misunderstanding what a herbicide does.

(c) (i) Most candidates were able to answer this question accurately, showing understanding that complementary base pairing was the reason for hybridisation. A minority incorrectly suggested that sticky ends or negative charges were a feasible explanation.

(ii) This question required the candidates to describe and explain the use of microarrays to identify the level of gene expression. Some understood well and stated from the beginning that the intensity of fluorescence indicates the level of gene expression.

Candidates frequently lost credit due to imprecise language, most commonly by not mentioning that it is cDNA that is involved. There was much confusion between cDNA and ssDNA, with the two being used interchangeably. Most mentioned that UV light is used. Some candidates incorrectly stated that the mRNA is converted to cDNA. Many candidates knew that hybridisation and fluorescence were involved and the finer detail was often missed.

Some confused this question about the level of gene expression with the use of a microarray to identify which genes are present and so wrote about different colours of fluorescence, e.g. green/red/yellow, instead of intensity of fluorescence.

Question 5

(a) Strong candidates were able to follow the logic behind this question and correctly calculated the expected number of each phenotype. Some misread the information given and gave the expected number from a cross between two dihybrid heterozygotes. A few candidates also confused the idea of expected number with expected ratio and wrote 1:1:1:1 or 9:3:3:1.

(b) The more able candidates were able to state that the value of chi squared was greater than the critical value at 3 degrees of freedom. They then went on to state that the results were significantly different to what was expected and not due to chance. The null hypothesis could be rejected. Some needed to apply their answer to this question and gave an explanation based on chi squared being higher or lower than the critical value.

(c) Candidates found this question challenging. Some knew that the genes may be linked and then mistakenly wrote that genes are inherited together rather than alleles. Most of the more able candidates correctly identified that crossing over may have occurred and stated that it took place in prophase I. A common mistake was to suggest that independent assortment had taken place. A minority of candidates stated that the number of parental phenotypes was greater than the number of recombinants.

Question 6

(a) (i) Many candidates could correctly identify all four structures and so gained full credit. Most candidates correctly identified the receptor, and a few referred to it as a receptor cell. Occasionally, G-protein and adenyl cyclase were stated the wrong way round.

(ii) Most candidates were able to correctly state at least one process that increased or decreased and many scored full credit.

(b) Most candidates had a good understanding of how the test strip could be used to test for the presence of glucose in urine by correctly identifying the two enzymes on the test strip and explaining their function. Some were imprecise about how to use the colour change on the test strip and needed to relate it to concentration of glucose. Many were able to give at least three reasons as to why the use of a biosensor was an advantage, the most common being speed of use, accuracy and reusability.

Question 7

(a) Strong responses stated that mitochondria produced ATP and that this had several functions in a neuromuscular junction. Many were able to mention the need for energy to make acetylcholine or to move its vesicles towards the presynaptic membrane. A common incorrect answer here was exocytosis of vesicles instead of acetylcholine. Fewer responses showed the need for energy in the sarcomere. More able candidates stated that ATP was required for myosin heads to detach from actin and then some contradicted themselves by saying that it was also needed for the formation of cross bridges, indicating the need for further understanding of the sliding filament theory of muscle contraction. Few were able to show that ATP is needed to pump calcium ions back into the sarcoplasmic reticulum.

(b) This question asked candidates to state whether they agreed with three statements and to explain why. The best responses dealt with each statement separately and explained correctly why they agreed with statements 1 and 3. Most found difficulty with statement 2 and could not link the influx of chloride ions with hyperpolarisation.

(c) The majority of candidates gained credit for a decrease in the transmission speed. Stronger answers linked their responses to a lack of saltatory conduction and few referred to shorter local circuits.

Question 8

(a) The main features of non-cyclic photophosphorylation were well understood by many candidates, with some comprehensive descriptions of the processes taking place. The majority of candidates stated that both photosystems would be involved, often going on to describe the photolysis of water by the oxygen evolving complex associated with photosystem II. Many commented on the role of photolysis in the replacement of electrons lost from photosystem II and that the electrons from this photosystem replaced those lost by photosystem I. Candidates were aware that reduced NADP is a product of non-cyclic photophosphorylation and only some appreciated that the electrons would be provided by photosystem I (and the protons from the photolysis of water). Some candidates gained the credit by stating that NADP would be the final electron acceptor. Very few candidates mentioned the photoactivation of chlorophyll. Some were unclear as to where the electrons released from photolysis or photosystems were going or where in the Z scheme the chemiosmosis and the photophosphorylation of ADP would take place. Many commented that a proton gradient would be established using the energy released from the electrons as they passed down the electron transport chain and that this would allow protons to flow through ATP synthase to produce ATP.

(b) Most candidates named triose phosphate as one intermediate of the Calvin cycle that could be used in other biosynthetic pathways and were able to offer a suitable product, such as glucose, lipids or starch. Some also mentioned glycerate phosphate and often linked it to the synthesis of glucose instead of amino acids or fatty acids. Weaker responses suggested a variety of incorrect molecules as intermediates, including NADPH and ATP.

(c) (i) The calculation of mean increase of carbon dioxide with increase in temperature was correctly performed by many candidates to achieve the answer of 0.10. Some drew a tangent to the line and used it to take their readings. Candidates needed to take care to round up correctly and express their answers to two decimal places. Some candidates used 2 as their denominator instead of 15. Rather than finding the difference between the two readings, some candidates added them and then divided by 15.

(ii) Most candidates were able to suggest at least one creditable reason why the rate of carbon dioxide uptake levelled off and then decreased after 20 °C, predominantly for stating that enzymes would be denatured at high temperatures, often describing the effect on the shape of the active site and its subsequent inability to form enzyme-substrate complexes. Many also appreciated that 20 °C was the optimum temperature for RUBISCO and other enzymes associated with the Calvin cycle which accounted for the highest rate of carbon dioxide uptake. Others also recognised that temperature was no longer a limiting factor while water availability could be; only rarely was carbon dioxide concentration identified as the limiting factor. Some commented that the stomata would close, although this was not linked to a lack of water or drought conditions, rather as a way of preventing water loss. There were occasional references to stomatal closure caused by the release of ABA due to water stress.

(iii) The curve to show the uptake of carbon dioxide on a cloudy day was correctly drawn beneath the curve for a sunny day by most candidates, although occasionally they placed their line above that on the graph or intersected it.

Question 9

(a) Explanations of the change in blood ADH concentration following the consumption of half a litre of water were variable and some candidates found this section particularly difficult. Stronger candidates appreciated that drinking water would increase the water potential of the blood and this would be detected by osmoreceptors in the hypothalamus, resulting in a reduction in the secretion of ADH. Many went on to state that the blood water potential would decrease as a consequence of reduced ADH release, although there were few references to less water being reabsorbed in the collecting duct. Stronger responses went on to add that more ADH would then be secreted to restore the water potential of the blood back to its set point and that the whole mechanism was an example of negative feedback.

Candidates need to improve on the precision in their responses. For example, by stating that ADH is secreted and not just produced or referring to water potential rather than blood water concentration or level. Some candidates misread the question and simply described the changes in blood ADH concentration over time without explaining them. Some referred to the secretion of ADH stopping and starting again, rather than decreasing and increasing. Many candidates were able to accrue some credit for correct descriptions of the changes in the water potential of the blood following the ingestion of water.

(b) There were some excellent accounts of the differences between the endocrine system and the nervous system, with stronger responses providing more than enough points to ensure they achieved full credit. Most began by stating that the endocrine system produces hormones that travel in the bloodstream while the nervous system produces impulses that travel in neurones, although some candidates lost credit for referring to nerves rather than neurones. Many understood that the nervous system has both a faster rate of transmission and rate of response but that the effects of the endocrine system are more widespread and longer lasting. Fewer candidates mentioned that the destination of nervous impulses are the muscles while hormones have a number of target cells or organs. Similarly, relatively few commented that hormones are chemical in nature while impulses are electrical.

Question 10

(a) Candidates found the first gap difficult; many suggested that a marker should be used to mark the animals and slightly more detail was required. Stronger responses proposed that non-toxic paint or dye should be used, or that the fur could be clipped, and there was occasional mention of collars or chips. The majority of candidates appreciated that there should be no reproduction, births or deaths affecting the population size during the study.

More able candidates understood that the Lincoln (or Lincoln-Peterson) Index would be used to estimate population size, although many candidates suggested Simpson's Index or Pearson's (coefficient of correlation). Most recognised that the method should be repeated, or replicated, for reliability.

(b) Most candidates were able to suggest at least one reason why Himalayan balsam has been listed as an alien species in the UK, most frequently due to its competition with native species for resources such as light, space or mineral ions. Although some candidates needed to qualify what the balsam would be competing for or simply stated 'food'. Many appreciated that it had a high reproductive rate so could overpopulate an area very quickly, reducing biodiversity and possibly causing extinction of some native species. Some mentioned that the balsam might introduce new diseases, or since it was non-native, would either not have any natural herbivores or be toxic to those that consumed it. Comments on how Himalayan balsam would attract insect pollinators away from native species were only infrequently seen. Weaker responses repeated the stem of the question without adding any further qualification.

BIOLOGY

Paper 9700/43
A Level Structured Questions

Key messages

To achieve highly in this paper, candidates need to be prepared to mentally process information and data and generate novel ideas. Candidates need to go further than memorising lists of ideas linked to syllabus learning outcomes in order to access the highest grades, since half the marks available are for questions designed to test the handling, applying and evaluating of information (AO2 skills).

General comments

The highest-performing candidates made intelligent use of the information in the question, particularly when directed to use data to draw conclusions. **Fig. 1.1** was the important reference point for all parts of **Question 1**. Some other questions that required candidates to show they had used the data provided were **Question 2(d)(iii)**, **Question 3(c)(i)**, **Question 3(d)(i)**, **Question 4(b)** and **Question 6(a)(iii)**. Weaker candidates sometimes attempted to answer these questions using memorised information only and needed to use or refer to the diagrams or data to gain credit.

A significant proportion of candidates omitted **Question 8(a)**, where the answer had to be added to a graph and was not prompted by the presence of a dotted line answer space. It is essential that candidates read all of the information provided to help them.

The main areas of knowledge candidates can improve on are being able to distinguish between the thylakoid membrane and the thylakoid space and understanding that the guard cell and the stoma are different things. Candidates also need to have a more realistic view of somatic gene therapy, understanding its technical challenges.

Comments on specific questions

Question 1

Candidates interpreted a schematic diagram of the processes occurring in a chloroplast.

(a) (i) Most correctly identified the individual components of the granum as thylakoids. Wrong answers included granum and granules.

(ii) Stronger answers clearly listed structural features and linked each feature to its functional role. The strongest answers stated that the thylakoid membrane is the site where the pigments, photosystems, electron carrier proteins or ATP synthase are found, and explained that it is the thylakoid membrane that carries out the related roles of photophosphorylation, chemiosmosis and ATP synthesis, while the lumen is where hydrogen ions accumulate. Most commonly, credit was gained for commenting on the large surface area of the stacked thylakoids and relating this to the function of increasing light absorption. Weaker candidates wrote freely about what they recalled about a granum and needed to obey the question rubric to link the structure or appearance of individual features of the granum and thylakoids to the function of each aspect. One major source of error for candidates was not differentiating between the thylakoid membrane and the thylakoid lumen. It was not acceptable to state 'thylakoids contain pigments'.

(b) (i) Most candidates correctly identified the metabolic cycle **C** in the chloroplast stroma as the Calvin cycle. Wrong answers included Krebs cycle and carbon dioxide fixation cycle.

(ii) The most successful descriptions of why **C** is described as a cycle referred to the regeneration of RuBP using five sixths of the TP available.

(c) (i) Product **B** was made from water in the granum and moved out of the chloroplast, and around half of candidates identified this as oxygen. Many who did not deduce this named ATP instead. The products of the light dependent reaction (ATP and reduced NADP) do not leave the chloroplast as was shown in **Fig. 1.1** to be the case for product **B**, and instead are used in cycle **C** in the stroma.

Product **D** from the Calvin cycle could be correctly named as triose phosphate, glucose or a later metabolite such as starch, glycerol, amino acids or fatty acids. Calvin cycle intermediates like GP were not correct, nor were light dependent reaction products like reduced NADP and ATP which some candidates gave as answers for **D**.

(ii) Many candidates correctly linked oxygen to aerobic respiration and glucose to being a source of food or energy. A minority of candidates made the error of referring to 'energy production' rather than energy release or provision from respiration of glucose. A few candidates also incorrectly stated that glucose releases energy 'for respiration' instead of by respiration. Candidates need to comment on the ecosystem aspect to the question and only a few realised glucose and its products are important in energy transfer in food chains and webs.

Question 2

This question explored the genetic variation level of biodiversity and its potential impact on the conservation of species diversity.

(a) Many candidates named the ecosystem level of biodiversity and the stronger candidates fully described the species level as including both the number of species and their relative abundance.

(b) Strong answers used the question information to explain that a database can store many DNA sequences so they can be accessed online and that computer algorithms can compare sequences and process large quantities of data quickly. Many answers listed general remembered points about bioinformatics and needed to address the demands of this specific question to gain the credit available.

(c) (i) Most candidates realised that *Anopheles* had most genetic variation; some needed to give the genus name alone as requested.

(ii) Many candidates identified that three kingdoms were represented in the table. The commonest wrong answer was two.

(d) (i) Candidates found it difficult to express why low genetic variation is potentially a problem for species survival. Some misinterpreted the word species and needed to realise this question was exploring the potential for species extinction.

Strong answers explained that genetic variation is necessary for selection to act on and that the species with low genetic variation will be less able to adapt to change. Some correctly argued that with genetic uniformity, a single disease or selection pressure could eliminate many members of a population or species at once. Stronger answers worked from the basis of the correct idea of low genetic variation as a small number of alleles existing in the population at a gene locus, perhaps just one. Weak answers often described an incorrect idea of low genetic variation as an allele having a low frequency in a population. The frequencies of the different alleles at a gene locus must add up to 100% so if one allele is at a low frequency one or more others must be at high frequency. The relative frequencies depend on selection pressures acting for or against certain alleles.

Arguments that stated the possibility of harmful recessive alleles coming together confused low genetic variation within the gene pool with inbreeding. Some wrong answers stated that 'low genetic variation causes inbreeding depression' whereas in fact the argument should be the other way round, that repeated inbreeding can reduce genetic variation. Very weak answers sought to explain how low genetic variation arises instead of explaining how it impacts on species survival as required by the question.

(ii) Most answers described the inverse correlation between genetic variation and conservation status or risk of extinction in an intelligible way, such as 'the lower the genetic variation the higher the conservation status' or 'as genetic variation increases the risk of extinction decreases'.

(iii) This question required skills of data analysis to evaluate a prediction. Often candidates had trouble highlighting the species that most obviously showed the prediction to be incorrect. Candidates tended to pick data randomly without selecting the examples which best illustrated the point they were trying to make. Vague answers that described one animal as having more variation than another animal but being more endangered did not gain credit**.** The major pieces of data that conflicted with the prediction were species with the highest and lowest levels of genetic variation not having low and high conservation status respectively, e.g. minke whale with the lowest variation being of low status, least concern, and chimpanzee with the highest variation being of high status, endangered. Some candidates correctly identified a pair of species with the same level of genetic variation and explained that they had different status, such as the whale as least concern and the lion as vulnerable. A few weaker answers did not refer to the data in **Fig. 2.2** at all, instead providing other items of recall to attempt to answer the question.

Question 3

The Hardy-Weinberg principle, continuous variation, plant hormones and graph analysis were tested in this question.

(a) Many candidates successfully calculated the number of heterozygous plants using the Hardy-Weinberg principle to reach the answer of 511. The commonest error in working that meant candidates arrived at a wrong answer but gained some credit for subsequent correct processing was giving *q* as 0.4 instead of the square root of 0.4. Another frequent error was using a calculated figure of *pq* instead of *2pq* to find the number of heterozygous plants. A few candidates tried to start by finding the proportion of plants showing the dominant purple phenotype in the population, instead of the recessive phenotype where all the red-flowered plants are homozygous recessive and so equal to the single term q^2.

(b) Most candidates used the information given to suggest that the flower colour showed continuous variation within the population due to its control by several genes, the influence on colour of the environment and the inability to divide the colours into discrete classes since they formed a gradual range. The weakest answers described individual flowers changing colour rather than the range of phenotypes in the population as a whole.

(c) (i) Candidates did relatively well with this question, using **Fig. 3.2** to explain that an increase in carbon dioxide concentration causes stomatal aperture size to decrease, and that this will lead to less water loss through stomata.

(ii) Strong candidates wrote full, correct answers to this AO1 (knowledge and understanding) question requiring recall of how abscisic acid causes the closure of stomata. Candidates needed to be able to distinguish between a guard cell and a stoma to gain credit. The details provided only gained credit with clear correct reference to either the pair of cells surrounding the stoma or the aperture or pore itself.

(d) (i) Most candidates gave some correct description of the results shown in **Fig. 3.3**. The strongest answers made general comments about the overall patterns and then supported these with figures stating day and units. Some candidates described patterns in the data over the time period without comparing between the different treatments.

(ii) Many candidates knew that when auxin binds to its receptors hydrogen ions are pumped into the cell wall, resulting in disruption of links between cellulose microfibrils in the wall.

Question 4

The question context was potato plants that were genetically modified to express proteins toxic to insects.

(a) (i) Strong candidates had no problem defining recombinant DNA and giving some detail of the technology that produces this, e.g. joining a gene to a vector to produce DNA that originates from two sources. Weak answers wrote about placing genes in a nucleus, cell or body with no suggestion that one piece of DNA has become physically joined to another. Others described one

'strand' of DNA joining to another, which implies the annealing of two strands to make a double helix, not the correct idea of ligase sealing the nicks in both sugar-phosphate backbones to join two linear stretches of DNA.

(ii) Most candidates scored for suggesting that the purpose of creating two different types of GM potato plants was to compare the effectiveness of each or to see which one worked best in killing insects.

(iii) The test on non-GM potato plants was correctly explained by most candidates as being a control experiment. Some candidates negated their answer by stating 'as a control variable'.

(b) Candidates were asked to use the data in **Table 4.1**. Analysis of the table led to a few strong answers explaining that both GM varieties **A** and **B** killed insect larvae, that growing GM potatoes will increase the yield of potatoes, and that this is particularly the case if **A** is grown since it produced the best results. The majority of answers covered only one or two of these points. Many answers seen needed to refer to **A** or **B**, and mention GM. The weakest responses made no mention of the question context or results table and listed benefits of GM such as reduced insecticide application from memory.

Question 5

Candidates analysed data relating to RQ and compared respiration in anaerobic conditions in mammals and yeast.

(a) Many candidates correctly selected malic acid as the respiratory substrate with the highest RQ and oleic acid as the respiratory substrate with the lowest RQ.

(b) Responses that scored most highly showed both knowledge and clear organisation, making clear which points were similarities shared by both types of organism, and which were differences, such as fermentation in mammals producing lactic acid and fermentation in yeast producing ethanol. Common errors were writing lactose or lactase instead of lactic acid (or lactate); stating that pyruvate is produced or just 'involved' rather than used in fermentation; and confusing reduced NAD, which is used in both types of fermentation, with oxidised NAD, which is regenerated in both types of fermentation. Few candidates noted that both types of respiration occur in the cytoplasm (some candidates thought the processes occurred in mitochondria). Some candidates thought that carbon dioxide is released in both processes, not just in yeast fermentation. Candidates often needed to improve on their descriptions of what is being oxidised and what is being reduced. Some answers discussed events that occur in glycolysis despite the question being limited to a description of fermentation only.

Question 6

Candidates interpreted the F2 results of a genetic cross involving a new mutation in tiger barbs.

(a) (i) A few candidates realised that as the transparent phenotype reappeared in the F2 generation, then it must be genetic or inherited. Some pointed out that the mutation had caused a new allele to form, or that the transparent phenotype is caused by a recessive allele. Many candidates struggled to express any pertinent ideas.

(ii) This question was done well with most candidates deriving the 9:3:3:1 ratio from the results in **Table 6.1**.

(iii) Most responses gained credit for stating that white stripes and transparent are recessive characteristics. Candidates who made a deeper analysis realised that two separate genes were involved, one for stripes (black or white) and a second gene for the body colour (gold or transparent). There was confusion about the meaning of a 9:3:3:1 ratio, with many candidates thinking this was evidence of linkage, whereas in fact it shows that the two genes assorted independently on separate autosomes. A few answers included the fact that this was a dihybrid cross.

(b) The main correct point made by candidates was to state that independent assortment happened in metaphase I. A very few candidates attempted to use symbols to explain how the two pairs of chromosomes, each with a dominant and recessive allele, could line up in two different ways giving

four possible gametes and hence the ratio of phenotypes seen in **Table 6.1**. The majority of candidates needed to explain the processes occurring in meiosis in the F1 fish that allowed the variation in the F2 fish shown in **Table 6.1** to arise as required by the question. Instead of focusing on how the wild-type heterozygous F1 fish produced the four classes of phenotypes in the table, most candidates reproduced a general answer from memory about how meiosis generates variation. Most candidates stated crossing-over would occur, although the 9:3:3:1 ratio shows that the two genes assorted independently and must be on separate chromosomes, making crossing-over irrelevant and in no way responsible for the combinations of traits seen in the F2 offspring.

Question 7

The three parts of this question related to muscle.

(a) (i) The commonest correct points made were mentioning the synaptic cleft and receptors. Some candidates gave one or two similarities in the distribution or function of ion channels in both, and some named the presynaptic and postsynaptic membranes (or sarcolemma). A small number of candidates knew that both have vesicles containing the neurotransmitter acetylcholine, and a very few mentioned large numbers of mitochondria. Few candidates were able to give four structural similarities shown by a neuromuscular junction and a cholinergic synapse to gain full credit. Some candidates spent time describing processes when the focus of the question was on comparing structural features.

(ii) This was an unusual question context, and many candidates applied their knowledge of the sliding filament theory to reason a correct answer. Clarity of language was important, as to gain credit the answer had to make clear that few calcium ions would bind to troponin, not many troponin molecules would change shape, the movement of tropomyosin would be less (than if calcium phosphate did not form) or little, and so on, stressing the reduced occurrence of each stage of the process. A few candidates considered the question from the angle of less phosphate being available to make ATP so less cross-bridges would break, and these answers also gained credit.

(b) Most candidates identified **A** in **Fig. 7.1** as adenyl cyclase; a smaller number gave the full name of **B** as protein kinase A.

Question 8

This question explored how light intensity affects plant physiology and gene expression.

(a) This question was commonly omitted by candidates as there was no dotted line for them to show their answer. This demonstrates the need for candidates to read all parts of the question paper carefully. Some candidates knew the area of the graph where light intensity acted as a limiting factor on the rate of photosynthesis and needed to place their **X** on the curve to gain credit.

(b) (i) Many candidates named reverse transcriptase as the enzyme that produces cDNA from an mRNA template. Wrong answers included DNA polymerase, RNA polymerase and RNA transcriptase.

(ii) The types of proteins that control gene expression in plants were most often named correctly as transcription factors, though some candidates focused on the plant context and were more specific, naming PIF, or gave the name of a sub-group of transcription factors like repressors.

(iii) Many candidates stated that in high light intensity the rate of photosynthesis is increased, and a small proportion went on to reason that because of this, plants would need to make more proteins and enzymes to be used in photosynthesis, such as rubisco and electron carrier proteins. Most candidates suggested that with more photosynthesis occurring there would just be more energy for the plant to switch on extra genes.

Question 9

The evolution and physiology of green lacewings formed the context for this question.

(a) (i) Most descriptions of how the tympanal organ of green lacewings could have evolved by natural selection gained some credit. The most frequently seen points were that the selection pressure is bats, and that lacewings with tympanal organs or that can detect high frequency sounds survive and reproduce. Many candidates needed to show understanding of the word ‘random’ and

contradicted their argument by stating ‘random mutation occurs so that tympanal organs develop’ or ‘random mutation occurs because lacewings need to escape from predators’. Any idea that the genetic change is due to a selection pressure or occurs as a result of a need negated the idea of randomness. The term ‘allele frequency’ needs to be better understood by candidates who suggested that ‘better-adapted lacewings have increased allele frequencies’ or ‘over time the allele frequency changes whereby individuals with the allele dominate those who do not have the allele’.

(ii) Careful respondents noted that the first event in the sequence took place in the receptor cell and that they needed to describe the sequence of events that would lead to an action potential in a separate cell, the sensory neurone. Weaker answers needed to make clear which of the two cells, receptor cell or sensory neurone, was being discussed and many candidates needed to realise that communication between two separate cells in the nervous system involved a synapse. In answers that attempted to describe what happens at a synapse between a receptor cell and a sensory neurone, some common errors appeared. One was writing that vesicles are released by exocytosis, or that vesicles bind to receptors on the post-synaptic membrane. Another was to confuse the neurone and the membrane, with answers wrongly stating that ions move ‘into the membrane’ instead of into the neurone. Some candidates lost credit for omitting to state ‘ions’ for components such as calcium ions and sodium ions, or for referring to them with incorrect symbols.

(b) Strong answers named sympatric speciation and referred to a behavioural difference giving rise to reproductive isolation. Some candidates wrote allopatric, and descriptions often did not match with the question information about the ranges of the two species overlapping in the modern day. Some candidates needed to name a form of speciation but still made a limited range of salient points.

Question 10

Candidates were often most successful at gaining credit for naming diseases for which genetic screening can be done, and elaborating on actions people might take if a test proves positive. Some candidates were able to describe how insulin can be produced in recombinant bacteria. Many candidates struggled to recall and organise knowledge about genetic technology to outline how it can be applied to medicine. Wording needed to be specific when candidates attempted to write about gene therapy. Answers often needed to consider which human cells should or could receive a normal allele and many candidates had an unrealistic view of the limitations of this approach, assuming that gene editing meant that all or any cells could simply be edited within a human body or even an unborn foetus. In general, answers showed difficulty moving from the concepts of altering DNA at the molecular level, to the whole organism physiological level, and the challenges of introducing new DNA to selected accessible cells.

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Key messages

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

When planning an investigation, candidates should make sure all parts of the investigation are addressed and that the work is set out in a logical way.

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

General comments

In **Question 1**, the common theme was the vitamin content of fruits. In the first part, the effect of ripeness on the ascorbic acid (vitamin C) concentration of apples was investigated. Candidates were asked to design an experimental method using the redox indicator DCPIP to measure the concentration of ascorbic acid in an apple extract solution. This was followed by candidates being asked to evaluate data from a second investigation into the β-carotene concentration of five different fruits.

Question 2 considered an investigation into the activity of trypsin from Atlantic salmon and domestic pigs. Data from the investigation was analysed by candidates; this included calculating a mean and standard deviation, then interpreting the results from a *t*-test.

Comments on specific questions

Question 1

(a) (i) The majority of candidates understood that size and ripeness of apples may not be proportional, although many candidates had difficulty expressing this idea succinctly. Candidates often read the information on page 2 of the question paper carefully and then referred to the sugar content, colour or softness of the apples; these ideas needed to be linked to ripeness to gain credit. Several candidates correctly noted that abiotic factors such as light intensity and water availability, or genetics may also affect the ripeness and diameter of apples. Explaining that apples have different shapes, and therefore the diameter may not be an accurate measure of their size, was not relevant to the question being asked.

(ii) Most candidates had read the information on page 2 of the question paper carefully, and therefore referred to the sugar content, colour, softness, and age of the apples. The strongest responses selected apples with a similar sugar content, colour, softness, or age. Alternatively, some candidates chose to measure the sugar content or colour of the apples. Using a Benedict's test to measure the sugar content or using a colour chart to compare colour were given credit. The use of a colorimeter was not appropriate in this context. Choosing apples with the same mass was not creditworthy, as neither mass nor diameter would give an accurate estimate of ripeness.

(b) Candidates were asked to sketch a line graph, including labelled axes, to show the predicted results. Most responses included correctly labelled axes with a line that increased and then decreased. Candidates usually noticed that the third bullet point stated 'decrease slightly in later days' and therefore drew a line that did not decrease back to the original ascorbic acid concentration. A few candidates confused the *x*-axis and *y*-axis labels.

(c) (i) Most candidates were able to correctly identify 90 cm^3 as the correct value for **step 1** of the dilution and 50 cm^3 as the correct value for **step 2**. The most common misconception was giving 100 cm^3 as the answer for **step 1**, when in fact the total volume of solution **A** should be 100 cm^3 which is achieved by adding 90 cm^3 of distilled water.

(ii) Candidates were familiar with this style of question, and most were able to describe some aspects of a suitable method to investigate the effect of ripening on the ascorbic acid concentration of apples. A few candidates gained full credit for this question. To score highly, both of the bullet points in the question stem needed to be addressed.

The investigation first required the preparation of apple extract solutions. Candidates needed to consider how they would change the independent variable. At least 5 apples should be picked from the tree on the same day; the apples should then be tested after a suitable number of days in storage (e.g. test apples after 2 days, 4 days, 6 days, 8 days and 10 days). Vague references to selecting apples at different stages of ripeness or preparing solutions with different concentrations of ascorbic acid were not creditworthy. The strongest responses made a clear reference to standardising the storage conditions of the apples, for example by maintaining a constant temperature and low humidity. Very cold temperatures are not suitable as this would not promote ripening. Some candidates specified that the apples should be from the same tree or of the same type/variety. Apples were identified as *Malus domestica* on page 2 of the question paper, therefore standardising the species of apple did not gain credit.

Most candidates were able to successfully describe a method to prepare an apple extract solution; for example, by grinding the apple using a pestle and mortar followed by filtering to remove solid debris. Candidates need to specify the apparatus used, rather than just 'grinding' or 'blending' the apple. Fewer candidates added additional details, such as removing the skin of the apple or using a set mass of apple when preparing the extract. Credit was often given for placing a standardised volume of apple extract solution in a conical flask.

Candidates were then required to describe a method to collect the results using the redox indicator DCPIP. Most responses described the dropwise addition of DCPIP until the end-point was reached; sometimes the end-point was incorrectly described as 'colourless' when DCPIP will actually remain blue. Some candidates demonstrated a good knowledge of practical technique by stating that the conical flask should be swirled during the procedure and that the bottom of the meniscus should be read at eye level. Vague references to reading the meniscus were not sufficient. References to using a water bath to standardise temperature did not gain credit as this would not be a feasible option for the apparatus shown in **Fig. 1.2**.

Most candidates considered how they would measure the dependent variable by recording the volume of DCPIP used. The terms 'value' or 'level' should not be used for volume. Measuring the number of drops of DCPIP added or measuring the time taken for DCPIP to change colour are not appropriate for this apparatus. Most candidates recognised the need for replicates in the investigation and linked these to the calculation of a mean. The term 'average' should not be used in a scientific context. To gain credit, responses needed to state clearly that at least three replicates are used to calculate a mean for each day of ripening. A single mean should not be taken across the entire investigation; therefore a precise description is required to avoid this misinterpretation.

Many responses incorporated some form of risk assessment, although stating that this investigation was 'low/medium risk' did not gain credit. Candidates needed to identify the hazard, state the risk associated with that hazard and clearly indicate the precaution that should be taken. It is not appropriate to consider the ascorbic acid within apples as an irritant; apples may be an allergen and wearing gloves would be a suitable precaution. Stronger risk assessments stated that DCPIP is an irritant, therefore gloves and eye protection should be worn. When using a knife, a suitable precaution to prevent injury is to cut away from your hand.

(d) It is important that candidates understand when to use both Pearson's linear correlation and Spearman's rank correlation. The majority of candidates who gained credit referred to the data being continuous or the data showing a normal distribution. A few candidates contradicted themselves by also stating that the data could not be ranked so were unable to gain credit; continuous data is also ordinal and can therefore be ranked. Several candidates started with the right idea of a linear relationship; this only gained credit if a further reference to a scatter diagram or graph was also included.

(e) Candidates were asked to use the data in **Fig. 1.3** to evaluate the conclusion given. Nearly all candidates gained credit by stating that apples have the second lowest β-carotene concentration, and many responses then provided at least one correct comparison of data to support this statement. To gain credit, data for both apples and one of cherry, orange or plum was required. It is important to give precise answers; statements such as 'apples have a low β-carotene concentration' or 'cherries have about 50 μg β-carotene per 100 g' were not sufficient.

Many candidates were familiar with the idea of checking whether error bars overlap or not. The error bars in **Fig. 1.3** represent ±1 standard deviation rather than standard error or 95% confidence intervals (95% CI). Conclusions about whether the difference between the means is statistically significant or not can only be made by calculating standard error or 95% CI, and then checking if these values overlap or not. The smaller standard deviation error bars for apples indicate that the spread of data for apples is lower than that for cherry, orange and plum.

The command term 'evaluate' indicates that credit is available for suggestions both 'for' and 'against' the conclusion. The strongest responses identified that no statistical test had been carried out, and often went on to note that only a small number of fruits had been tested. References to there being a small sample size did not gain credit, unless candidates went on to state that it was the limited number of fruit species they were referring to.

Question 2

(a) (i) Several candidates correctly identified the independent variable as the type or source of trypsin. A common error was to state 'different animal species' as the independent variable; this did not gain credit without an additional reference to trypsin. Another common error was to state 'concentration of trypsin' as the independent variable. Most candidates gained credit by identifying time taken as the dependent variable. Only a few candidates confused the independent and dependent variables.

(ii) Candidates were asked to state one variable that should be standardised in the experiment. The pH of the trypsin solution was correctly given by some candidates. Whilst many candidates identified the gelatine cube as a variable to be standardised, a common error was to refer only to the size of the cube. Creditworthy responses included standardising the surface area, volume, and mass of the gelatine cube.

(b) (i) The majority of candidates were able to correctly calculate the mean time taken for trypsin from domestic pigs to break down the gelatine cube as 131.1 seconds. Very few candidates gave an incorrect value for the mean.

(ii) Most candidates were able to complete the calculation, giving the standard deviation as 3.2 seconds. Candidates should give their answer to the same number of significant figures as the other values in the table; therefore $s = 3$ seconds did not gain credit.

(iii) Many candidates gained full credit for this question, showing a good ability to analyse statistical data. Most responses correctly stated that the critical value was 2.074 (at 22 degrees of freedom and $p = 0.05$). Therefore, the null hypothesis is rejected as the calculated *t*-value of 2.663 is greater than the critical value. Having rejected the null hypothesis, candidates were then able to conclude that there is a significant difference between the time taken for trypsin from Atlantic salmon and trypsin from domestic pigs to break down a gelatine cube.

Some candidates selected the wrong critical value; this was often due to the selection of the number of degrees of freedom not being fully understood. Many were then able to secure some credit by correctly explaining that the null hypothesis is rejected when the calculated value is greater than their (incorrect) critical value. A few candidates chose to accept the null hypothesis (at $p = 0.05$) and therefore could not achieve full credit.

(iv) Several candidates were able to conclude that the activity of trypsin from Atlantic salmon was higher at 20 °C than the activity of trypsin from domestic pigs. To gain credit, candidates also needed to be able to explain this difference. Stating that the optimum temperature of trypsin from pigs is 38 °C, or that the optimum temperatures of trypsin from salmon and trypsin from pigs are different, did not gain credit. Credit was awarded to those candidates who made a comparative statement about the enzymes. For example, trypsin from salmon has a lower optimum temperature than trypsin from pigs. A few other correct comparative statements were also seen, such as trypsin

from salmon forms enzyme-substrate complexes at a faster rate than trypsin from pigs. References to the denaturing of enzymes were not creditworthy, as the investigation was carried out at 20 °C. A few candidates noted correctly that the increased activity of trypsin from salmon at 20 °C may be due to the active site being more efficient at binding to the substrate than the active site of trypsin from pigs.

The difference in the activity of the two enzymes could also be explained by stating that trypsin from salmon is adapted to colder temperatures compared to trypsin from pigs. A few candidates described how the adaptations of trypsin from salmon can be linked to the selection pressures of a lower temperature environment. Candidates needed to make comparative statements; simply stating that trypsin from salmon is adapted to work in a variety of temperatures was not creditworthy.

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Key messages

- Candidates should be encouraged to read the whole question prior to answering.
- Certain themes appear commonly, including planning an investigation and statistical analysis of data. It is important that candidates practise these skills in preparation for the exam.
- When planning an investigation, the work should be set out in a logical way and be detailed enough to let another person follow it.
- Candidates should read the instructions carefully, especially when asked to use specific phrases such as, 'fully support', 'partially support' or 'does not support', when determining if there is sufficient evidence to support a conclusion.

General comments

Candidates were able to analyse statistical data and discuss the conclusions that could be made from this with ease. Weaker candidates were challenged when providing a method for an ecological investigation.

Comments on specific questions

Question 1

(a) Candidates were asked to state two variables which were standardised in the investigation. Candidates should state only two variables, rather than list many, as those who did this often included the independent or dependent variables. On occasion, candidates needed to be more precise in order to gain credit. For example, stating that the depth of the rock pools was measured rather than stating that the rock pools were measured at their deepest point.

(b) (i) Many candidates were able to correctly state a null hypothesis. Some referred to there being no difference between the depth of the rock pool and the species diversity. Candidates need to refer to there being no correlation to gain credit. The null hypothesis must match the statistical test being used.

(ii) Candidates who correctly identified that 32 pairs of measurements were used were able to choose the correct critical value from the table and often went on to attain full credit. Some candidates were confused about which statistical test was being used and attempted to calculate degrees of freedom which led to them choosing the incorrect critical value.

(iii) There were many detailed reasons provided for this question, with the vast majority of candidates attaining credit for referring to the data not being normally distributed. A few candidates needed to be more precise in identifying that both sets of data need to be continuous for Pearson's linear correlation coefficient to be chosen. Some of the best responses referred to the scatter diagram not suggesting a linear correlation.

(c) This question asked candidates to explain why it was difficult for researchers to repeat the investigation from the information provided. Those candidates who identified aspects of the investigation which were unknown gained credit. For example, the precise location of the rocky shore was unknown, as was which specific rock pools were sampled. Many candidates made suggestions about aspects of the investigation which would change if a researcher were to return to the rocky shore on a different day. Whilst these suggestions were detailed, they did not answer the question being asked.

(d) There were some clear and detailed plans which gained full credit, outlining a method that was set out in a logical order and detailed enough for another person to follow.

Those candidates who carried out a belt transect, laying tape measures from the low-water mark (LWM) to the high-water mark (HWM) and placing quadrats at regular intervals along the tape measure, gained the most credit. Some candidates suggested a random sampling method, which would not allow them to determine how the distribution and abundance of the different species of algae varied along the rocky shore from the LWM to the HWM.

Successful answers included precise details about what measurements to record in each quadrat. Some candidates needed to develop their answer by stating they would count the number of different algal species present in each quadrat, rather than just counting the algae present. Other successful answers included a method for determining the abundance of each algal species within each quadrat, such as percentage cover or use of the Braun Blanquet measurement.

Candidates needed to be clear that they would replicate the belt transect at least three times starting at different positions along the shoreline at the low-water mark, and then calculate a mean for each quadrat sampled at the same position along the transect. Answers stating that they would repeat the whole experiment three times and calculate a mean did not gain credit. Many responses mentioned replicating the belt transect a suitable number of times in the correct positions, but this was sometimes linked to calculating an average. It is important that candidates use the term mean in scientific work as a matter of course.

Safety issues should be specific to the investigation. Many candidates gained credit for correctly identifying a hazard, risk and a suitable precaution. A few candidates just referred to being careful when walking on a rocky shore or when handling the algae and these were insufficient to gain credit.

Question 2

(a) Most candidates were able to suggest a method to accurately measure the length of a shoot which was curved. The most common responses were to use a tape measure, to straighten the shoot prior to measuring, or to cut a piece of string the same length as the shoot and then measure that.

(b) (i) Candidates were asked to calculate the 95% confidence interval (CI) for one of the batches of seedlings. The formula for this calculation was provided and candidates needed to correctly read the mean shoot length from the graph and calculate the standard error value, to then be able to then calculate the 95% CI. Credit was given for answers in the format of $\bar{x} \pm (2 \times \text{SE})$, with 42 ± 3.3 being the correct answer. Candidates who went on to take away 3.3 from the mean value of 42 and add 3.3 to the mean value of 42, providing the extremes of the confidence interval, also gained credit. Both of these values were required to gain credit.

(ii) Many candidates were able to successfully state that, as the 95% CI error bars did not overlap, this meant that the difference between the means was significant.

(c) Candidates were asked to suggest and explain the effects of ABA and SA on the growth of the rice seedlings. Many answers just included data from the graphs. Successful responses referred to what this meant in terms of the growth of the rice seedlings, with ABA reducing growth and SA increasing growth. Credit was also given to those candidates who made a comparison on the growth of the seedlings when both hormones were used in combination compared with when the hormones were just used on their own.

(d) There were some clear answers produced for this question, with some candidates suggesting ways to track the hormones using dyes and collecting results on day 1 and day 5. Some responses needed developing beyond watering the seedlings, with the more successful answers including a suitable method for applying the hormone solutions to the roots only. These included adding the hormone solution to the soil or spraying the roots with the hormone solution prior to planting in soil.

The question asked for a method which would give similar results to the experiment where the shoots were sprayed with hormones. Answers which just stated that a named condition would be kept the same needed to go on and refer to it being the same as in the shoot spraying experiment to gain credit.

(e) (i) Candidates were asked to use specific descriptions when completing a table to show how the expression of three genes was affected by the presence of the plant hormones. The vast majority of candidates only used the descriptions provided. Successful candidates had compared the mean relative quantities of mRNA for the named hormone with when just water was applied.

(ii) This question required candidates to state and explain whether the evidence provided on the graphs fully supported, partially supported or did not support two conclusions made about the effects of the mixture of the two hormones on two of the genes. Many candidates were able to correctly state if the evidence supported these conclusions or not, by using the terminology provided in the question. Some candidates needed to develop their answers further by referring to the relative quantities of mRNA found when the mixture was applied to the seedlings compared to when they were applied separately. For conclusion 1, candidates needed to compare the quantity of mRNA when the mixture of hormones was applied to when ABA was applied alone. For conclusion 2, candidates needed to compare the quantity of mRNA when the mixture of hormones was applied to when ABA was applied alone and when SA or water was applied alone.

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Key messages

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

When planning an investigation, candidates should make sure all parts of the investigation are addressed and that the work is set out in a logical way.

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

General comments

In **Question 1**, the common theme was the vitamin content of fruits. In the first part, the effect of ripeness on the ascorbic acid (vitamin C) concentration of apples was investigated. Candidates were asked to design an experimental method using the redox indicator DCPIP to measure the concentration of ascorbic acid in an apple extract solution. This was followed by candidates being asked to evaluate data from a second investigation into the β-carotene concentration of five different fruits.

Question 2 considered an investigation into the activity of trypsin from Atlantic salmon and domestic pigs. Data from the investigation was analysed by candidates; this included calculating a mean and standard deviation, then interpreting the results from a *t*-test.

Comments on specific questions

Question 1

(a) (i) The majority of candidates understood that size and ripeness of apples may not be proportional, although many candidates had difficulty expressing this idea succinctly. Candidates often read the information on page 2 of the question paper carefully and then referred to the sugar content, colour or softness of the apples; these ideas needed to be linked to ripeness to gain credit. Several candidates correctly noted that abiotic factors such as light intensity and water availability, or genetics may also affect the ripeness and diameter of apples. Explaining that apples have different shapes, and therefore the diameter may not be an accurate measure of their size, was not relevant to the question being asked.

(ii) Most candidates had read the information on page 2 of the question paper carefully, and therefore referred to the sugar content, colour, softness, and age of the apples. The strongest responses selected apples with a similar sugar content, colour, softness, or age. Alternatively, some candidates chose to measure the sugar content or colour of the apples. Using a Benedict's test to measure the sugar content or using a colour chart to compare colour were given credit. The use of a colorimeter was not appropriate in this context. Choosing apples with the same mass was not creditworthy, as neither mass nor diameter would give an accurate estimate of ripeness.

(b) Candidates were asked to sketch a line graph, including labelled axes, to show the predicted results. Most responses included correctly labelled axes with a line that increased and then decreased. Candidates usually noticed that the third bullet point stated 'decrease slightly in later days' and therefore drew a line that did not decrease back to the original ascorbic acid concentration. A few candidates confused the *x*-axis and *y*-axis labels.

(c) (i) Most candidates were able to correctly identify 90 cm^3 as the correct value for **step 1** of the dilution and 50 cm^3 as the correct value for **step 2**. The most common misconception was giving 100 cm^3 as the answer for **step 1**, when in fact the total volume of solution **A** should be 100 cm^3 which is achieved by adding 90 cm^3 of distilled water.

(ii) Candidates were familiar with this style of question, and most were able to describe some aspects of a suitable method to investigate the effect of ripening on the ascorbic acid concentration of apples. A few candidates gained full credit for this question. To score highly, both of the bullet points in the question stem needed to be addressed.

The investigation first required the preparation of apple extract solutions. Candidates needed to consider how they would change the independent variable. At least 5 apples should be picked from the tree on the same day; the apples should then be tested after a suitable number of days in storage (e.g. test apples after 2 days, 4 days, 6 days, 8 days and 10 days). Vague references to selecting apples at different stages of ripeness or preparing solutions with different concentrations of ascorbic acid were not creditworthy. The strongest responses made a clear reference to standardising the storage conditions of the apples, for example by maintaining a constant temperature and low humidity. Very cold temperatures are not suitable as this would not promote ripening. Some candidates specified that the apples should be from the same tree or of the same type/variety. Apples were identified as *Malus domestica* on page 2 of the question paper, therefore standardising the species of apple did not gain credit.

Most candidates were able to successfully describe a method to prepare an apple extract solution; for example, by grinding the apple using a pestle and mortar followed by filtering to remove solid debris. Candidates need to specify the apparatus used, rather than just 'grinding' or 'blending' the apple. Fewer candidates added additional details, such as removing the skin of the apple or using a set mass of apple when preparing the extract. Credit was often given for placing a standardised volume of apple extract solution in a conical flask.

Candidates were then required to describe a method to collect the results using the redox indicator DCPIP. Most responses described the dropwise addition of DCPIP until the end-point was reached; sometimes the end-point was incorrectly described as 'colourless' when DCPIP will actually remain blue. Some candidates demonstrated a good knowledge of practical technique by stating that the conical flask should be swirled during the procedure and that the bottom of the meniscus should be read at eye level. Vague references to reading the meniscus were not sufficient. References to using a water bath to standardise temperature did not gain credit as this would not be a feasible option for the apparatus shown in **Fig. 1.2**.

Most candidates considered how they would measure the dependent variable by recording the volume of DCPIP used. The terms 'value' or 'level' should not be used for volume. Measuring the number of drops of DCPIP added or measuring the time taken for DCPIP to change colour are not appropriate for this apparatus. Most candidates recognised the need for replicates in the investigation and linked these to the calculation of a mean. The term 'average' should not be used in a scientific context. To gain credit, responses needed to state clearly that at least three replicates are used to calculate a mean for each day of ripening. A single mean should not be taken across the entire investigation; therefore a precise description is required to avoid this misinterpretation.

Many responses incorporated some form of risk assessment, although stating that this investigation was 'low/medium risk' did not gain credit. Candidates needed to identify the hazard, state the risk associated with that hazard and clearly indicate the precaution that should be taken. It is not appropriate to consider the ascorbic acid within apples as an irritant; apples may be an allergen and wearing gloves would be a suitable precaution. Stronger risk assessments stated that DCPIP is an irritant, therefore gloves and eye protection should be worn. When using a knife, a suitable precaution to prevent injury is to cut away from your hand.

(d) It is important that candidates understand when to use both Pearson's linear correlation and Spearman's rank correlation. The majority of candidates who gained credit referred to the data being continuous or the data showing a normal distribution. A few candidates contradicted themselves by also stating that the data could not be ranked so were unable to gain credit; continuous data is also ordinal and can therefore be ranked. Several candidates started with the right idea of a linear relationship; this only gained credit if a further reference to a scatter diagram or graph was also included.

(e) Candidates were asked to use the data in **Fig. 1.3** to evaluate the conclusion given. Nearly all candidates gained credit by stating that apples have the second lowest β-carotene concentration, and many responses then provided at least one correct comparison of data to support this statement. To gain credit, data for both apples and one of cherry, orange or plum was required. It is important to give precise answers; statements such as 'apples have a low β-carotene concentration' or 'cherries have about 50 μg β-carotene per 100 g' were not sufficient.

Many candidates were familiar with the idea of checking whether error bars overlap or not. The error bars in **Fig. 1.3** represent ±1 standard deviation rather than standard error or 95% confidence intervals (95% CI). Conclusions about whether the difference between the means is statistically significant or not can only be made by calculating standard error or 95% CI, and then checking if these values overlap or not. The smaller standard deviation error bars for apples indicate that the spread of data for apples is lower than that for cherry, orange and plum.

The command term 'evaluate' indicates that credit is available for suggestions both 'for' and 'against' the conclusion. The strongest responses identified that no statistical test had been carried out, and often went on to note that only a small number of fruits had been tested. References to there being a small sample size did not gain credit, unless candidates went on to state that it was the limited number of fruit species they were referring to.

Question 2

(a) (i) Several candidates correctly identified the independent variable as the type or source of trypsin. A common error was to state 'different animal species' as the independent variable; this did not gain credit without an additional reference to trypsin. Another common error was to state 'concentration of trypsin' as the independent variable. Most candidates gained credit by identifying time taken as the dependent variable. Only a few candidates confused the independent and dependent variables.

(ii) Candidates were asked to state one variable that should be standardised in the experiment. The pH of the trypsin solution was correctly given by some candidates. Whilst many candidates identified the gelatine cube as a variable to be standardised, a common error was to refer only to the size of the cube. Creditworthy responses included standardising the surface area, volume, and mass of the gelatine cube.

(b) (i) The majority of candidates were able to correctly calculate the mean time taken for trypsin from domestic pigs to break down the gelatine cube as 131.1 seconds. Very few candidates gave an incorrect value for the mean.

(ii) Most candidates were able to complete the calculation, giving the standard deviation as 3.2 seconds. Candidates should give their answer to the same number of significant figures as the other values in the table; therefore $s = 3$ seconds did not gain credit.

(iii) Many candidates gained full credit for this question, showing a good ability to analyse statistical data. Most responses correctly stated that the critical value was 2.074 (at 22 degrees of freedom and $p = 0.05$). Therefore, the null hypothesis is rejected as the calculated *t*-value of 2.663 is greater than the critical value. Having rejected the null hypothesis, candidates were then able to conclude that there is a significant difference between the time taken for trypsin from Atlantic salmon and trypsin from domestic pigs to break down a gelatine cube.

Some candidates selected the wrong critical value; this was often due to the selection of the number of degrees of freedom not being fully understood. Many were then able to secure some credit by correctly explaining that the null hypothesis is rejected when the calculated value is greater than their (incorrect) critical value. A few candidates chose to accept the null hypothesis (at $p = 0.05$) and therefore could not achieve full credit.

(iv) Several candidates were able to conclude that the activity of trypsin from Atlantic salmon was higher at 20 °C than the activity of trypsin from domestic pigs. To gain credit, candidates also needed to be able to explain this difference. Stating that the optimum temperature of trypsin from pigs is 38 °C, or that the optimum temperatures of trypsin from salmon and trypsin from pigs are different, did not gain credit. Credit was awarded to those candidates who made a comparative statement about the enzymes. For example, trypsin from salmon has a lower optimum temperature than trypsin from pigs. A few other correct comparative statements were also seen, such as trypsin

from salmon forms enzyme-substrate complexes at a faster rate than trypsin from pigs. References to the denaturing of enzymes were not creditworthy, as the investigation was carried out at 20 °C. A few candidates noted correctly that the increased activity of trypsin from salmon at 20 °C may be due to the active site being more efficient at binding to the substrate than the active site of trypsin from pigs.

The difference in the activity of the two enzymes could also be explained by stating that trypsin from salmon is adapted to colder temperatures compared to trypsin from pigs. A few candidates described how the adaptations of trypsin from salmon can be linked to the selection pressures of a lower temperature environment. Candidates needed to make comparative statements; simply stating that trypsin from salmon is adapted to work in a variety of temperatures was not creditworthy.